THE ENGINEER

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Fuel Research Board's Report

LAST week the Fuel Research Board issued its report for the year 1954. It records progress in the study of the constitution of coal, including the study to reveal sources of germanium-rich material since germanium is in demand by the electronics industry. As solid fuel continues to be the main source of domestic heating the reduction of domestic smoke largely depends upon the availability of smokeless fuel, and the report states that such solid fuel can be produced in ordinary equipment by carbonising weakly-coking coals. Part of the report is devoted to synthesis of oils from coal, particularly the Fischer-Tropsch process, and in a section dealing with fuel oils it is stated that work has been carried out to devise a system to break down emulsions of sea-water in fuel oil at sea to give an oil containing not more than 1 per cent of sea-water by volume. On the question of smoke elimination for forced draught boilers it is stated that the certain principles adopted for natural draught boilers can be applied to forced draught units and that equipment so designed was fitted to a Lancashire boiler and eliminated smoke at all loads. Boiler availability has been studied and radioactive tracers have assisted in the investigations into the formation of bonded deposits. According to the report the reduction of the catalytic activity of the iron oxide would effect an improvement. Work on the development of combustion chambers for coal-fired gas turbines has been concentrated on the design of the Station's straight-through combustion chamber and a unit is being built to work under pressure and tested when coupled to a gas turbine. Valuable information on the room-heating efficiencies with different kinds of heating has resulted from measurements made in the Calorimeter building and the report mentions the use of a chimney throat restrictor to improve efficiency and that useful heat given by an open fire increases as the rate of burning is reduced.

Lloyd's Register Book

LLOYD'S REGISTER OF SHIPPING is publishing a completely revised *Register Book*, the first major modification of layout and content since 1890. From the pocket edition of 1764, the first year of publication, *Lloyd's Register Book* gradually expanded into one large volume by about 1890 and as the volume of world tonnage increased the single volume has grown into the two volumes of to-day. In its new form the *Register of Ships* appears as a single volume which is neither greater in weight nor in bulk than one of the two volumes previously in use. This has been achieved mainly by the successful research to produce a paper, which is 60 per cent in thickness of the old and equal to it in tearing strength and opacity, and to a minor extent by the transference of certain items of technical information to the Appendix. The new arrangement means a more important role for the Supplements to the *Register Book* and these will appear in cumulative form at monthly intervals and contain information regarding recent periodical surveys of ships built to the Society's class together with a record of change of name, ownership, flag, tonnage for all ships in the *Register*, and involving up to 30,000 alterations each year. New entries amounting to approximately 4000 a year will be published simultaneously, but not in cumulative form, and be suitably indexed. The single volume *Register* has resulted in the Appendix becoming Volume II which is appreciably smaller in size than the new *Register* and the first three sections contain technical data relating to ships other than tankers, tankers and refrigerated cargo installations respectively. Other information appearing in Volume II includes lists of ships whose names have been changed, ships listed under nationality and tonnage divisions, shipbuilders together with existing ships built by them, and data on wet and dry docks.

Irish Transport Exhibition

A HISTORICAL exhibition on Irish transport has been opened in Belfast to commemorate the golden jubilee of the city transport department. This exhibition, which will remain open until the end of August, is thought to be the largest and most representative of its kind ever held in Ireland, and it covers many aspects of the country's land, river and sea transport from prehistoric times to the present day. It is being staged in three places in the city—the museum, the transport store at Queen's Quay, and in Belfast Castle. At the museum there are being shown dug-out canoes, model coracles, the Edens Osborne Collection of bicycles and tricycles, J. B. Dunlop's bicycle fitted with pneumatic tyres which he invented and patented in 1889 ; a Minerva motor-cycle of 1903 and a Belfast-built Chambers car of 1908. At the transport store are exhibited two Belfast trams, one converted from a horse-car to electric traction in 1905 and one of 1929, also the underframe of a horse-tram (1873–1905) ; a steam tram of the Portstewart Tramway (1883–1926) ; a trailer car of the Portrush-Giant's Causeway Tramway, the first hydro-electric railway in the world (1883–1949) ; an electric tram of the Bessbrook-Newry Tramway (1885–1948) ; a light railway locomotive of the Larne Aluminium Railway, dated 1906 ; a 3rd class railway coach of the Dublin-Kingstown line (D.W.W.R.) dating from about 1840 ; a 1st and 2nd class coupé coach of the Dundalk, Newry and Greenore Railway of about 1905 ; and, when it arrives in August, a tank locomotive (2–4–2) of the G.N.R. last used on the D.N. & G.R. (1873–1951). In addition there are two horse-drawn fire engines from Larne and Belfast, an Irish jaunting car and an Irish tinker's caravan. At Belfast Castle there are pictures and models of passenger sailing ships and steamships which have been in service in Ireland, while many road and rail models will be shown in the lecture hall of the Museum, as well as other relics.

Opening of London County Council's Outfall Works Extension

ON Friday, July 1st, the Minister of Housing and Local Government, Mr. Duncan Sandys, opened the new primary sedimentation plant at the London County Council's Northern Outfall Works at Beckton. The new facilities comprise a diversion from the existing trunk sewers, a screen house, sixteen primary sedimentation tanks with a total capacity of 20,000,000 gallons, and an auxiliary outfall channel. The tanks are of reinforced concrete construction, each one being 270ft long and 75ft wide, with a working depth of 12ft ; they are founded on piles, of which 8500 were driven, and 72,000 cubic yards of concrete is embodied in their construction. A somewhat detailed description of these new works and of other improvements at the Northern Outfall Works was published in our last issue (page 9). At the opening ceremony, the chairman of the London County Council, Mr. Norman Prichard, presided. An explanation of the new works was given by Mr. Joseph Rawlinson, the Council's chief engineer, and a vote of thanks to the Minister was moved by Mr. E. E. Woods, the chairman of the Council's rivers and drainage committee. Mr. Rawlinson pointed out, during the course of his address, that considerable attention had been given in the design of the new works to reducing fluid friction losses, for the head available though the new works was only 3ft, at high water of spring tides.

Disposal of Stormwater Through Sewers

A TECHNICAL committee has been appointed by the Ministry of Housing and Local Government to consider the present method of disposing of stormwater through overflows on sewers under modern conditions. The terms of reference of the committee are : "To study and report upon the practice relating to stormwater overflows on sewers, and the disposal of stormwater and to make recommendations." This is an aspect of sewerage design which has not been fully investigated since the Royal Commission on Sewage Disposal reported early this century. Since then, such factors as the rising consumption of water, the increasing use of public sewers for the disposal of trade wastes and the virtual disappearance of horses from the towns, have changed conditions considerably. Where sewers carry both foul sewage and rainwater the flow is subject to very wide fluctuations, and it has always been a common practice to incorporate overflows which allow spilling when the volume is greatly increased in times of storm. The nature of these overflows, which usually spill directly into rivers and streams, is a subject which the committee will consider. The committee, whose chairman is Mr. H. W. Coales, a deputy chief engineer of the Ministry, includes technical officers from Government Departments, local authorities and river boards, and consulting engineers. The technical secretary is Mr. J. W. M. Hawksworth.

London Route "C" Tube

LAST week a member of the British Transport Commission explained to a House of Commons Committee the benefits which would result from the construction of the proposed route "C" tube connecting Walthamstow to Victoria via King's Cross and Oxford Circus. It was pointed out that the new tube would be the equivalent of a high capacity roadway across the central area and that it would link Victoria with the West End and with the three northern main line railway termini at Euston, St. Pancras and King's Cross. Overcrowding over a section on the Piccadilly line would be relieved and the suburbs of Edmonton, Tottenham, Enfield and Walthamstow would be better served. The expansion of business into the West End had increased traffic to Victoria, for which only a circuitous route was available, and it was explained that more accommodation planned in the suburbs and in the new towns called for improved facilities from Euston, St. Pancras and King's Cross. Route "C," it was claimed, would effect a general improvement in underground travel and, in particular, would relieve the pressure on the most crowded sections of the Piccadilly, Northern, District and Central lines. An incidental benefit of such relief would be the improvement in efficiency by the reduction of delays at the stations. It was expected that route "C" would cause the peak traffic density to fall from 22,000 to 15,000 passengers per hour between Victoria and Charing Cross on the District line, and from 19,000 to 16,000 passengers per hour between Euston and Charing Cross on the Northern line. These improvements were a certainty, it was explained, since diversions of traffic would be attracted to route "C" by reason of the considerable reduction in journey times amounting to, on the average, fifty per cent.

Design of a Comprehensive Computer for Handling Complex Creep Problems

By A. J. KENNEDY,* Ph.D., B.Sc., A.M.I.E.E., F.Inst.P.

No. II—(*Concluded from page 4, July 1st*)

In the last decade, very great technological advances have been achieved in the development of high-temperature machines, such as gas turbines. These advances have been dependent, in part at least, on the successful production of materials capable of withstanding the rigorous working conditions imposed, and progress in the field is closely tied up with the question of whether even better materials can be evolved in the future. A number of special metallurgical and physical problems arise in the design of these machines, such as those of creep, fatigue, oxidation, thermal shock and structural transformation. It is certainly not the purpose of the present article to review the whole of this very complex field, the object being rather to consider one of these factors, that of creep under conditions where stress and temperature are not kept constant, and to examine the possibility of computing the behaviour fairly rapidly from the minimum experimental data.

General Behaviour of Metals

It has been noted above that a parameter A can be used to represent the recovery behaviour of metals. In principle, there is no reason why A should not take any value from $A=0$ (complete recovery during the unload period) to $A=\infty$ (zero recovery). The original experiments on this type of behaviour, conducted on lead at about room temperature[10] and on copper at about 200 deg. Cent.,[11] gave values for A of 15 and 8 respectively. It was natural to assume that A varied from metal to metal even when the tests were conducted in ranges where the same kind of creep curve was exhibited (the same value of time exponent, p, in the creep equation). In fact, for given τ and ρ values a number of metals (lead, cadmium, zinc, copper, magnesium, tin and iron) at different stresses and temperatures (but for all of which $p=0\cdot3$) provided values of the recovered fraction, n, which were distributed about a mean as shown in Fig. 8 (inset). Using equation (2), this mean n value provides a value for A of about 9·0, which (again remembering that A can lie in the range from zero to infinity) is near to the values of 15 and 8 quoted above from other tests. It would appear, then, that for a given value of p, A does not vary very greatly. If the conditions of the test are so changed that the value of p changes, then there certainly is an alteration in the value of A. This is shown in Fig. 8. The continuous curve drawn is the rectangular hyperbola $Ap=3\cdot0$. Accepting this as an empirical formulation of this dependence, we may substitute for A in equation (2), and we find that there are now no arbitrary parameters; the whole behaviour is determined by β and p only, for any given values of τ and ρ.

The results, however, show an experimental scatter, and on the basis of these results on a limited number of metals, over a limited range of conditions, it is not possible to propose that the generalisations made are universally valid. However, the trend of these results is sufficiently striking to lead us to consider how such a trend might arise. The argument may be developed as follows.

The magnitude of the transient exhibited on first loading we have already denoted by β. If the transient on reloading is δ, we have, using the previous notation, that $n=\delta/\beta$.

A number of ways have been proposed for introducing temperature into the transient creep equation. One formulation, which has support from Mott[17] and from Dorn[18] is an exponential of the form

$$\varepsilon=\psi[t\exp(-Q_c/RT)] \quad . \quad . \quad . \quad (7)$$

where ψ is some function (in our case a power function), Q_c is the activation energy for transient creep, T the absolute temperature and R the gas constant. Comparing the creep equation $\varepsilon=\beta t^p$, we may write

$$\beta=\beta_0\exp(-pQ_c/RT) \quad . \quad . \quad . \quad (8)$$

As far as δ is concerned, we wish to establish how this quantity varies with the recovery temperature for a fixed pre-history (fixed τ, ρ, creep stress and temperature), knowing that for a wholly isothermal interruption test δ/β varies very little with temperature. Noting the similar functions which arise in formulating creep and recovery, we suggest a dependence of the form

$$f(\delta)=f(\delta_0)\exp(-pQ_R/RT) \quad . \quad . \quad (9)$$

where Q_R is the activation energy for recovery.

Thus the results of the tests reported above (Fig. 8) would arise if $f(\delta)/\beta$ were a function of n only and if $Q_c\simeq Q_R$. In particular, taking $f(\delta)=\delta/(\beta-\delta)$ we derive $n/(1-n)$ as the relevant n-function in accordance with equation (2). The values of Q_c and Q_R can be determined independently and for pure lead we obtain $Q_c\simeq18$ kcal/mole and $Q_R\simeq19\cdot5$ kcal/mole. This is a satisfactory confirmation of their near-equality, but the problem of the dependence of A on p remains. If $Q_R\sim Q_c=\Delta Q$, a small quantity, then clearly there will be a temperature dependence of n (for a fixed p) which may be masked by experimental scatter. The value of p would also depend on temperature and would follow the same trend as that shown in Fig. 9 only if $Q_c>Q_R$. It is not possible at present to sort out this problem any further until accurate individual determinations of Q_c and Q_R are available for different metals. The important point at present is that Q_c and Q_R appear to be very near in value and that the observations may possibly be capable of reconciliation on some such basis as the foregoing. It is possible that under extreme test conditions, certain metals, and particularly the more complex alloys, may exhibit quite a different behaviour; in this respect, much experiment remains to be done.

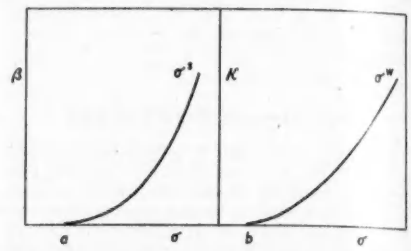

Fig. 9—Responses of the β and κ components to stress

The question of the temperature and stress dependence of the quantities β and κ (or their equivalents in other empirical formulæ) has received a great deal of consideration. The temperature dependence of β has already been noted to satisfy the form of equation (8).

A thermally activated process, such as the activation of dislocations over free energy barriers may be considered as biased directionally by the application of an external stress, and thus treated, expressions of the form

$$\varepsilon=B\exp(-Q_c/RT)\sinh(D\sigma/RT) \quad . \quad (10)$$

are obtained. The stress appears in such an equation within a quantity which is a function of σ/T. This is not wholly acceptable as far as metals are concerned, and Dorn[18] has noted that most of the evidence suggests that σ should appear in a separable function, at least for the case of high temperature creep. It is possible, then, that ε is proportional to $\exp(G\sigma)$ at high stresses and simply to σ^q at low stresses, with G and q constants. This division of the stress into two ranges is reminiscent of the division made by Wyatt

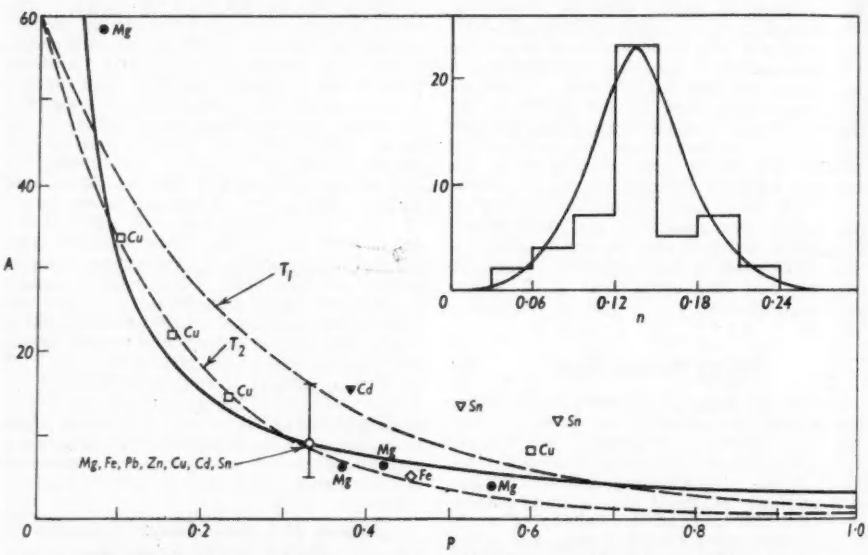

Fig. 8—Relationships between A and p for various metals compared with the hyperbola (continuous lines) $Ap=300$. Inset, distribution of the value of the recovered fraction n for a number of metals

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in distinguishing low stress (logarithmic) from high stress (cubic) creep.

Even though opinions differ about detailed forms, these equations are sufficiently representative for the problem being considered here. One important divergence in opinion is that whereas in the Andrade cubic model the β-flow tends to a limiting value as σ increases (although the κ-flow increases continuously) in the other approaches no such limit arises. It is possible that such a limit is real and significant, but as this arises at high creep rates it does not come within the scope of the present survey which is restricted, as has been said, to the region of practical importance.

This section has not been designed as a comprehensive review of creep theories and empirical formulations. The intention has been to extract some sort of broad pattern of behaviour so that the nature of the computing problem may be revealed more clearly. For our purposes, the variations of both β and κ with stress and with temperature can be expressed as functions of these variables by using exponential or power functions, together with limits if necessary.

The Problem of Comprehensive Computation

The problem of computing how a given metal specimen will behave under complex stress and temperature conditions is certainly not solved, then, but at least some suggestions as to the manner in which it might be handled can be made.

We start with a basic transmission line type of network of the kind developed for the creep and recovery analogue (Fig. 5, *ante*). This reproduces the behaviour under isothermal conditions with the stress history restricted to on-off periods. As it stands, we can reproduce the creep behaviour provided we know β, κ, p and A (knowledge of ε_0 being trivial). The quantities β and κ are easily set because the analogue scale can be chosen as we wish, in any arbitrary manner, and therefore only the ratio β/κ is significant. As κ can be controlled independently this offers no problem. The important problems are those of setting up the values of p and A. An ideal machine would presumably have setting dials of some kind, upon which were inscribed values of p and A. Some such system is very necessary in a practical computer, and its solution is certainly the next step in the development of the full machine. The value of p (that is, the shape of the creep curve) is largely determined by the values of R (for fixed C and C^1 values) with the value of A largely controlled by the leak resistor R'. However, R' influences the character of forward creep, quite obviously, and thus adjustment affects both p and A. The results on metals are consistent with this interdependence, as Fig. 8 shows, and if one were convinced that such a relationship was universal, a unit for setting p and A would be easily designed as only one independent variable need be handled. In our present state of knowledge it would appear to be safer to attempt to set each separately according to the values of p and A obtained by experiment. Such a process may involve successive approximations in setting, or the development of a servo system. The problem is interesting technically and is one on which work is now going forward. When this is achieved, the computer will be in a more practical form to use, but still as limited in the scope of the problems it can handle as before.

One of the limitations is brought about by the fact that the response of the machine is linear with applied voltage (the scale of the creep curve obtained is linearly related to the voltage). As we know, the responses of the β and κ components to stress are non-linear, as has been said, and they take the forms shown in Fig. 9. In the creep range acceptable technologically, we may say that each quantity requires for its definition a limit (a and b) and a power function of the form $C\sigma^s$ and $D\sigma^w$ (see Fig. 9). Units with response characteristics of this form are quite standard and could be interposed between the voltage source and the relevant network. In particular, it might be a reasonable procedure to divide the curve into sections and reproduce it by linear segments.

We have therefore,, at our disposal the parameters β, κ, p, A, a, b, C, D, S and W, the first four of which are set up on the network, and the rest on the response unit, as it might be called. Eight fairly short-term tests would suffice to establish these quantities, together with one long term test over the time-range of interest. The machine will then solve any variable stress problem provided the whole test is isothermal.

The introduction of a facility to handle generalized temperature changes is certainly the most difficult technical problem at the moment. In this case we must change not only the nature of the response curves of Fig. 10, but also modify the network itself so that the creep and recovery properties alter in the correct way. Can this be considered a practical problem at all ? On the face of it, probably not, but in approaching this question one remembers that the basic network used, although itself simple, reproduces the fairly complex features of metal behaviour. If, then, this analogue is anything more than a fortuitous mathematical device, and is, indeed, a genuine physical analogue of the types of process involved, then we must believe it possible to reproduce the temperature dependence in a reasonably simple manner. For instance, there are reasons for believing that temperature changes may be reproduced by changing the C/C' ratio together with a uniform change in all the resistors. The optimism regarding the possibility of developing a comprehensive computer arises, therefore, not because this has been worked out technically, but because one hopes that if a genuine analogy has been achieved for the more simple cases then its extension to the general case should be possible.

Other questions of practicality and economics remain. In the first place, any creep computations must surely always be based on creep knowledge obtained from direct experiment on the metal in question ; there is no indication at present that creep design can proceed *a priori*, as it were, from knowledge of composition and treatment. At present, creep tests are lengthy, and a single specimen may occupy a fairly expensive machine for years. The capital, labour and running costs may run into hundreds of pounds a test, with a whole creep laboratory, occupying no small space, consuming thousands of pounds a year. A large testing programme is therefore expensive and time-consuming, and at the end of it one has specific data only for the conditions of the tests. These one takes to be representative of the conditions which the material will encounter in practical use. Such practical conditions are, however, complex, as we know. Temperature and stress vary in a complicated way and these conditions should therefore be simulated in our testing. Is this economical ? Possibly, if the conditions for which the materials are required are sufficiently standard, but if technological developments occur continuously, with each new machine or engine working under new complex conditions, then it may be quite impossible to keep pace with the amount of experimentation required. Because of these demands it may be well worth while to think in terms of a computer, and to modify test procedure accordingly. Thus a restricted series of experiments on each new material of interest to those working with high-temperature machines would provide the parameters from which the behaviour could be computed, only one of these tests necessarily being over a long time. These parameters would not normally be of any great use because direct computation is not possible, but coupled with the analogue computer any complex history can be imposed and the result deduced quickly with reasonable accuracy.

In its present form, the machine speed is such that creep over periods of years can be simulated in tens of minutes, but the speed has here been deliberately chosen so that reading-out from motor-driven dials can be comfortably achieved. By using automatic high-speed recording, and reducing the time constants of the circuits, a very greatly increased speed is possible. Because of this, one machine could comfortably handle a great number of problems, and would appear to be economically reasonable if its services can be made available to a fairly large field of engineering interest. The widespread installation of temperature and stress programmers and the execution of lengthy complex tests would therefore be avoided and testing would be much reduced.

The question of interest need not always be that of finding out how a given material, with given parameters, responds to a variety of conditions. The converse problem is also important : given a particular requirement in engineering, what is the best available material ? If data were available in standard form, a number of materials could be run through very quickly and the best selected. The results of experiments (as reported in the symposium on intermittent effects, just published[20]) show that we can no longer ignore these complexities when designing for conditions very near to the limits which the materials can stand. In other fields, special computers have been devised to deal with complex problems by analogue means. These have provided a service to industries and organisations which need quick solutions to problems which would otherwise involve laborious measurement, as is the case with heat transfer problems, and there is no reason why some such development should not take place in the field of creep design.

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Engineering Models at The Institution of Civil Engineers' Conversazione

THE Institution of Civil Engineers held its annual conversazione on Thursday, June 23rd, and the customary display of engineering models was to be seen in the library during the course of the evening. The scope of the display was sufficiently wide to include something of interest to members in all of the diverse fields of the civil engineering profession. Scientific and research apparatus, however, seemed particularly prominent this year. There were also a number of models of engineering projects now in course of construction, such as the B.O.A.C. maintenance base at London Airport, and the Tehran water supply scheme. Some of the exhibits, covering subjects which have not been dealt with in these columns before, have been selected for description below.

Helical Motion in a Curved Open Channel.—A visual demonstration of the growth of helical motion in a curved channel, showing how one river bed may control another and how both may be controlled from far upstream, was given by Mr. T. M. Prus-Chacinski (Imperial College). Along a curved channel the water tends to follow a helical path, the flow near the bed being deflected greatly towards the inner wall while the upper water drifts gradually towards the outer wall. This phenomenon was observed by Leonardo da Vinci in the fifteenth century. It was first investigated scientifically by Professor J. Thomson in this country, who in 1876 gave a substantially correct explanation of the origin of the helical flow. The motions are difficult to measure and even more difficult to express mathematically, so that, until recently, very little further progress was achieved despite its practical significance in relation to the fundamentals of the transport of silt, the meanderings of rivers and river control and irrigation.

Essentially the helical flow in a bend is generated by the centrifugal superelevation of the water surface towards the outer wall in conjunction with friction, which greatly decelerates water flowing very near the bed. Centrifugal force, proportional to the square of the velocity, causes the fast upper water to heap up against the outer wall and the resulting pressure squeezes the slow-moving lower water towards the inner wall. In effect, the path of the water is a screw or helix of non-uniform pitch and, in general, the magnitude of the difference of speeds of upper and lower water governs the strength of the resulting helical component of the motion.

The aim of the work at Imperial College is to give a guide in the design of works adjacent to the bends of rivers and canals, particularly those which carry much silt or whose beds are liable to scour. The motion in a bend turns out to be very sensitive to any spin or irregularity which may exist in the water before it enters the bend. Indeed, the problem as a whole, although concerning silt, cannot be investigated in a channel whose bed is of erodible sand, which is liable to complicate or obscure the interaction of the many forces brought to play by the bend itself. There is no fundamental difference between the flow of a fluid over a solid bed and the flow of the same fluid over a loose bed of sand, though the latter seldom remains constant during a long experiment. Accordingly the investigation has been done mainly in channels with non-erodible beds, and in this way many actions which otherwise would have escaped notice have come to light, we are informed.

These experiments form part of a long series of investigations carried out by various research students of the Hawksley hydraulic laboratory (Imperial College) under the guidance of Professor C. M. White. In this work experiments with sand beds provide first a general picture of the overall result ; the causes are then elucidated by experiments with solid beds, while finally the conclusions are verified by further experiments with sand. Among the more interesting findings, some of which it is thought may possibly never have been previously described, or indeed observed, are :—(1) The helical component, once it has developed, dissipates very slowly and so persists for great distances ; (2) the helical pattern is very sensitive to the presence of any cross currents which may happen to exist at the entrance to the channel ; (3) the helix causes great variation in the rate of transport of silt in different parts of the bend, and governs the pattern of erosion and deposition; (4) helical motion occurs both with rough and with smooth beds, in very wide and in very narrow channels, and in bends of cross-section other than rectangular ; (5) patterns consisting of multiple helices are frequent ; (6) helical flow can be controlled artificially by vanes or other devices ; (7) motions of the present kind are intimately connected with the meandering of natural rivers.

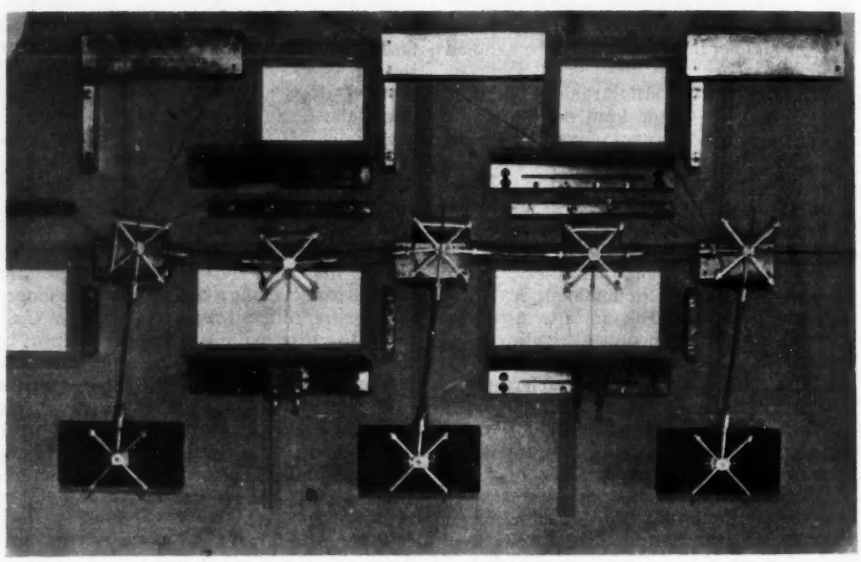
While at the present stage of the work it is considered premature to describe its application to particular river works, yet it is also thought that there is a wide field in which it could have a considerable influence on design. The apparatus exhibited consists of a simplified meandering channel constructed of "Perspex." The channel consists of two bends of 39in radius and 45 deg. deflection connected by a straight piece 18in long. The cross-section is rectangular, 6in wide.

Vessel for the Removal of Mud.—A model of a vessel designed for the disintegration and removal of compacted mud fron ships' berths, dock entrances, and so on, was exhibited by H. Randal Steward (Chief Engineer, The Proprietors of Hay's Wharf, Ltd.). The vessel is 63ft long by 20ft beam, by 3ft 9in draught, with a working depth up to 30ft, and is self propelled. It operates by the discharging, through specially designed nozzles, of a mixture of air and water at high pressure. The equipment comprises two diesel-engine-driven air compressors, two diesel-engine-driven two-stage centrifugal water pumps and a small diesel-engine-driven auxiliary set with general service pump, starting air compressor and lighting generator. Engine cooling is by closed circulation through large radiators mounted on deck. The crane jib lifts the nozzle frame and automatically stows the air and water hoses. The nozzle frame can be rotated by power at any depth.

This vessel is the prototype of an improved and enlarged version of an existing similar craft "Jean" which has been in operation on the Thames for the past ten years. One of its more interesting and successful achievements was the recovery of a dock gate from the North West entrance of the Surrey Commercial Dock which had been blown up by enemy action and was sunk in the river. The "Jean" blew a hole 15ft to 20ft deep by some 80ft diameter in the mud on the river bed which enabled the dock gate to be recovered by floating crane. Illustrations of the vessel at work on various jobs were shown.

Plastic Collapse Experiments.—The accompanying illustrations show a method of model analysis for the plastic collapse of stiff-jointed plane frames, exhibited by Professor J. W. H. King and D. E. Jenkins (Queen Mary College). The model represents a typical stiff-jointed frame, wherein points at which bending into the plastic range is liable to develop under overload are fitted with "analogous" plastic hinges.

A typical hinge of this kind is shown in the diagram. The four members of the structural frame are pinned to it, but the hinge itself consists of a rigid cross-shaped assembly, connected with the frame members by short lengths of spring steel, which act as simple struts. When a simple strut is end loaded, the curve of longitudinal deflection against load follows the same general form as that of rotation against moment for a beam subjected to a bending moment increasing into the plastic range. Hence by using such a strut as a restraint on the movement of a free hinge, the hinge can be caused to behave in the manner of a short length of beam so loaded as to pass beyond its elastic range, i.e. as a "plastic hinge."



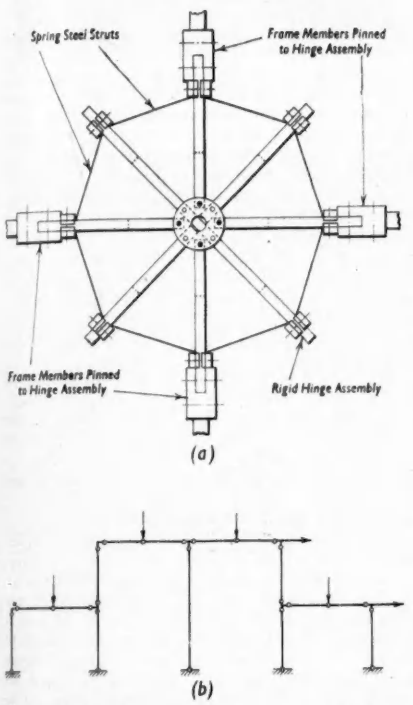
Model of stiff-jointed plane frame, with "analogous" hinges to determine mode of plastic collapse. The method of applying loads can be seen

The moment at which the plastic condition develops can be controlled by the strut stiffness and the leverage used, so that a variety of relative stiffnesses of members is readily obtainable. Furthermore, although the model simulates plastic failure, it is in fact behaving elastically throughout, and the tests are non-destructive. Repeated tests with modifications to particular members are therefore readily carried out. Considerable experimental work has indicated the method is as accurate as normal methods of analysis, we are informed, and possesses the advantage that the correct solution for any conditions of loading or stiffness is determined at once whereas analysis calls for a comparison of several possible solutions.

The hinge can be readily modified to suit different structural configurations. In practice the struts are given a slight initial deflection, as the direction of deflection affects the end condition. A typical model set up for experiment, and showing how the loads are applied is shown in the photograph reproduced herewith. The other illustration shows diagramatically the model exhibited at the conversazione. This particular structure has 159 possible modes of collapse, all of which would need to be con-

sidered in making a theoretical approach.

Tests on Long Welded Rails.—Tests on the use of long welded rails up to 800 yards in length have been carried out by the Western Region of British Railways. The apparatus used was exhibited by Mr. M. G. R. Smith (Chief Civil Engineer, Western Region). Due to the variations that occur in the temperature of the rails considerable stresses are set up in the track. It has been established that expansion or contraction which relieves these stresses takes place only over a limited length at each end of the rail and is modified by the frictional resistance of the rail and resistance of the ballast against the sleepers. Special " breather switches " are fitted at the ends of the rails to allow these movements to take place. It is desirable that information should be obtained on the movements and stresses that occur in the track and the exhibit showed methods which have been adopted for continuously recording these movements and for obtaining data on the most suitable rail fastening and sleepers to be used.



(*a*) Detail of " analogous " hinge for a rectangular joint in the structure. Strut length 1·125in.
(*b*) Line diagram of frame exhibited. The small circles show possible plastic hinge positions. The frame has 159 possible modes of collapse.

Plastic collapse analysis of plane frame

Soil Mechanics Apparatus.—Mr. H. Q. Golder (Soil Mechanics, Ltd.), exhibited a triaxial testing machine for use up to 800 lb per square inch in the determination of the shear strength of soils and soft rocks, and a vane apparatus developed to measure, in the laboratory, the shear strength of soils and particularly that of sensitive clays.

In the so-called triaxial compression test for determining the strength of a cohesive soil, a cylinder of this soil is subjected to a constant lateral pressure and a vertical stress which increases until failure occurs. Normally lateral pressures from 0–100 lb per square inch are used. In the case of soft rocks (soft sandstones, shales, mudstones, &c.), the measured compressive strength is often critical by comparison with the stresses which would be applied to the rock. In order to know whether they behave as frictional materials, high lateral pressures are needed during the strength measurements in construction problems involving such rocks.

The exhibit was developed to apply lateral pressures of up to 1000 lb per square inch. To avoid the danger of explosion at high pressures an all-liquid pressure system was decided upon. The pressure is therefore provided by a vane pump which has a constant pressure output of 1000 lb per square inch and pumps oil around a closed circuit. A bleeder valve in this circuit provides a " rake-off " at any desired pressure below the maximum. The pressure in the oil is transferred through a rubber diaphragm to the air-free water in the triaxial cell. A vertical stress is then applied through a proving ring at a constant rate of strain until shear failure occurs. Samples varying from $\frac{3}{4}$in diameter by $1\frac{1}{2}$in in length to 4in by 8in can be tested in this way.

The small vane tester was developed to measure the shear strength of soils without having to extrude them from the original sampling tube. Thus the minimum amount of handling is assured and after testing the soil can be further examined. The vane consists of a rod from which four small blades project, set at right angles to each other, measuring $\frac{1}{4}$in by $\frac{3}{4}$in each. The rod is screwed co-axially into a disc which is graduated around its circumference and carries a calibrated spiral spring. One end of the spring is fixed to the edge of the disc, the innermost end being connected to a worm and gear wheel. A torque is applied slowly and gradually increased in magnitude until the soil ruptures. This is indicated by a constant reading of a pointer on the edge of the disc. The stress and strain at failure are then known and the shear strength can be obtained. Values below 100 lb per square foot can be measured.

Royal Show at Nottingham

No. II—(*Continued from page* 13, *July* 1*st*)

THE Royal Agricultural Society's 107th annual show opened at Wollaton Park, Nottingham, last Tuesday morning, July 5th, and closes this evening, July 8th. The site of the show itself occupies no less than 165 acres, the largest area so far occupied by a Royal Show. Among the many visitors to the show—and the total on the opening day was 11,686—are representatives of a number of overseas countries, including students visiting this country under the Colombo Plan. H.M. The Queen is again the Patron of the show, and this year the president is the Duke of Portland, K.G. Among the many interesting displays of a special character which attract numerous visitors, there is an exhibition of early farm equipment. This exhibition illustrates the part played by the Royal Agricultural Society in the development of farming tools and equipment from the time of its first show in 1839 to the time the " Royal " was first held at Nottingham in 1888.

On no less than 600 trade stands there are presented examples of all kinds of machinery and equipment which play such an important part in modern agriculture in this country and overseas. Here, we continue a description of some of the new machines and implements which have come to our notice during a preliminary survey of the exhibits.

In our illustration Fig. 5, there is shown an apparatus which is used for spraying sheep to protect them against maggot fly at seasons when the more orthodox practice of sheep dipping is inconvenient. This equipment, known as the Cooper-Allman spray race, is exhibited by E. Allman and Co., Ltd., Birdham Road, Chichester, and has been awarded one of the Royal Agricultural Society's silver medals. As may be gathered from the illustration, the race consists of a wooden floor, with sides of corrugated metal. Along it a series of jets project at intervals from spray-booms placed at varying heights, and a spray-boom is also supported above the race. Fan-shaped sprays are directed at the sheep from overhead and along the sides of the race so that the sheep are well covered as they pass through.

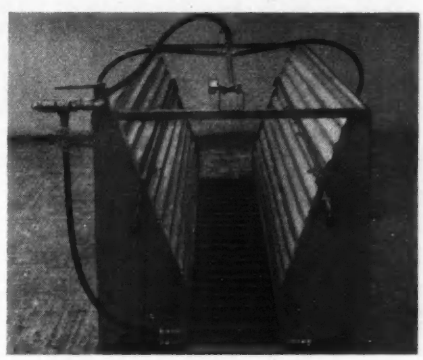


Fig. 5—Sheep spray race

Power is provided by a complete pumping assembly or by a pump driven from the power take-off of a tractor, the spraying liquid being taken through hoses from any suitable reservoirs, such as two 40-gallon drums. Two 20-gallon tanks are fitted on either side of the race to collect the excess wash. The spray race can be lifted by two men and conveniently used on any site that is fairly level.

The root harvesting machinery exhibited by Catchpole Engineering Company, Ltd., 19, Hatter Street, Bury St. Edmunds, Suffolk, includes the " Premier Shotbolt " potato harvester (Fig. 4), which underwent several trials last

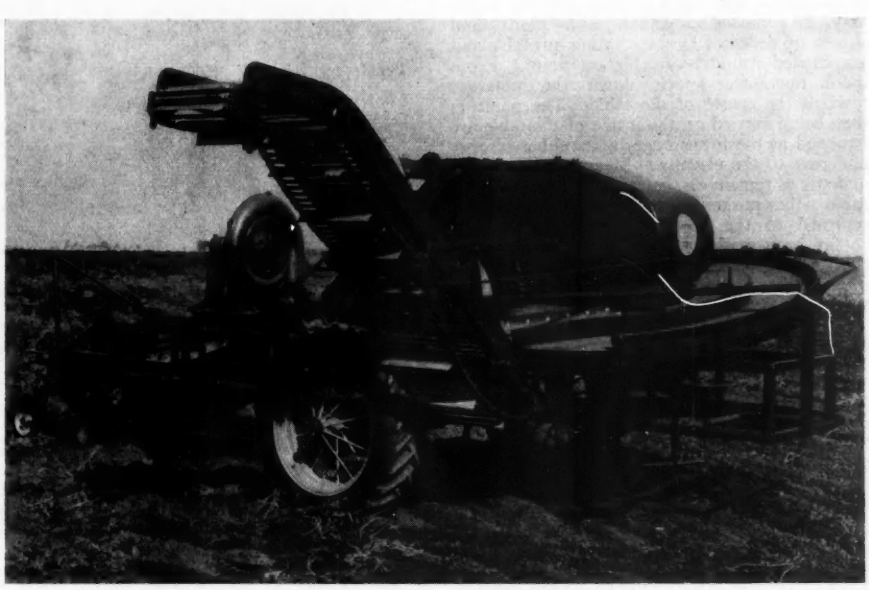


Fig. 4—Complete potato harvester operated by tractor power

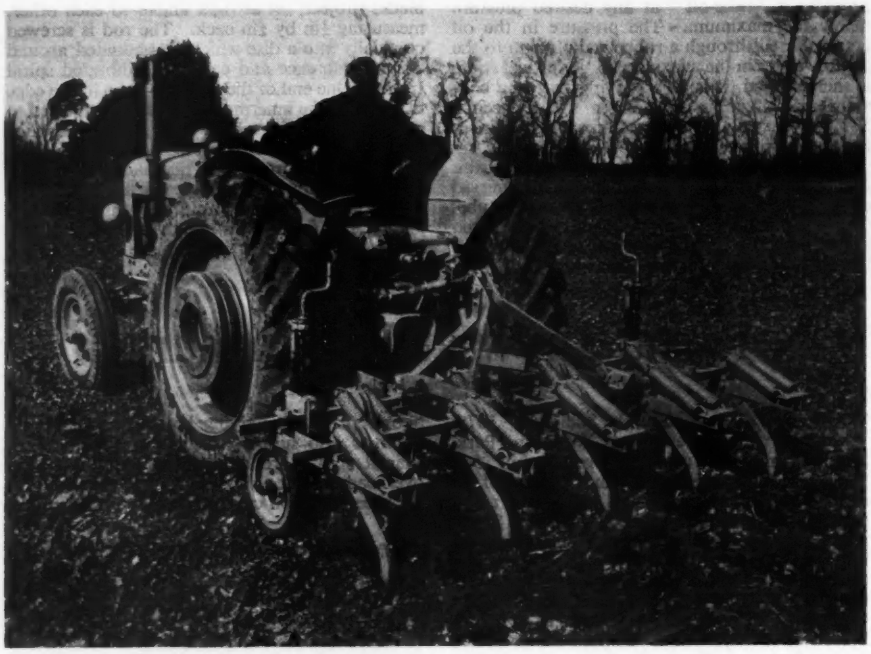


Fig. 6—Spring tine cultivator fitted to tractor-mounted toolbar

season. The arrangement of this machine is such that the potato roots are lifted from the ground by a share and rod-link chain, the chain being agitated to remove a good deal of the earth. Mounted above the rod-link chain, and approximately 2ft from the share, there is a three-tined scuffler, which moves rapidly from side to side, its purpose being to break up the clods and riddle the earth through the chain. The scuffler also helps to shake earth from weeds and other trash which may be lifted with the potato roots. At the delivery end of the rod-link chain the potatoes, together with earth, stones and haulm, fall into an air stream which is created by a high-pressure fan, the outlet from the ducting through which the air passes being just below the delivery end of the chain. The purpose of the air stream is to remove the haulm and any weeds which are then returned, through a hood, to the ground. The potatoes, and also any clods and stones, pass through the air stream on to a semi-automatic inclined separating turntable which rotates in a clockwise direction. Some of the potatoes, upon reaching the surface of this turntable, immediately roll down to its outer edge and then on to an elevator which carries them to an accompanying trailer. Other potatoes which may be massed together with clods and stones are deflected by the rotating turntable and are carried round to its highest point. From there operators knock down the potatoes towards the centre of the table. The potatoes then being carried on the inside of the table are removed at the lower edge by a rubber scraper and pass to the elevator. Meanwhile the earth and stones remain on the outer edge of the turntable ; they are removed by another scraper and returned to the ground. Trials which have so far been made on this machine have shown that sufficient power for its operation, even under difficult conditions, can be derived from the power take-off of a tractor.

Cultivating implements of several kinds, operated on the hydraulic lift system of the "Major" tractor, are demonstrated by Ford Motor Company, Ltd., Dagenham, Essex. Many of the implements being shown are joint productions of the Ford Company and Ransomes, Sims and Jefferies, Ltd., Ipswich. Among these products are two tool bars, designated C73 and C74, which are attached to a tractor by the three-point linkage. They are "general-purpose" implements, adaptable as rigid tine or spring tine cultivators, three-row ridging ploughs, steerage hoes, or beet lifters. Tine bars, headstock and rubber-tyred depth wheels are common components of each tool bar, the C73 taking tine bars 8ft 4in long, which are normally spaced at 10in intervals to give a normal cultivating width of 7ft 6in. On the C74 the tine bars are 10ft 2in long, and with eleven tines spaced at intervals of 10in there is a cultivating width of approximately 9ft. The C73 tool bar is shown in Fig. 6 fitted with nine spring-loaded tines, the standard points being 2½in wide. If during operation any obstruction is encountered, the tines pivot back and the action of the springs automatically returns them to their normal working position.

In recent years there has been a good deal of development work devoted to machines for forage harvesting, especially in connection with silage making. One of the firms which is showing this class of machinery is Silorators, Ltd., 103, Park Street, London, W.1. The Mark II "Silorator" was described in our issue of July 16, 1954. It is a tractor-towed machine, driven by a power take-off shaft, and it is here

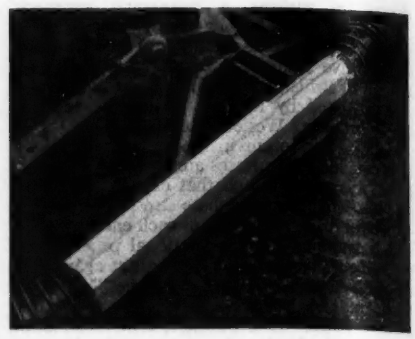


Fig. 8—Steel spring guard for tractor power take-off shaft

in particular that a necessary improvement has been introduced. Much attention is now being concentrated on the elimination of accident risk when operating farm machinery but it is not always easy to provide an adequate guard to a power take-off shaft or to a revolving coupling. Silorators Ltd. has devised the steel power take-off guard illustrated in Fig. 8. It consists of opposed pairs of single-cone springs which cover and protect the couplings whilst permitting their free movement. The shafting between the couplings is protected by telescopic U-section steel forms. Although the guard was designed originally to meet the requirements of the firm's forage harvester it can, of course, be produced to other dimensions for all kinds of agricultural machines.

An exhibit of particular interest on the stand of Marshall, Sons and Co., Ltd., Gainsborough, and John Fowler and Co. (Leeds), Ltd., is the "Track-Marshall" diesel crawler tractor which is shown in Fig. 7. This machine, which is a joint product of the two firms, is best described as a general-purpose crawler tractor for heavy agricultural duty and medium-scale earth-moving operations. Its engine is a Perkins four-cylinder diesel, with a bore of 4½in and stroke of 4½in, which gives 48 b.h.p. at a speed of 1600 r.p.m. A 12V induction heater and a primer pump are provided as cold starting aids. The engine power is transmitted through a 14in diameter single-plate clutch, and six forward speeds and two reverse speeds are provided by a three-speed layshaft and high-low reduction to differential gear. The final drive is through spur gearing. The forward

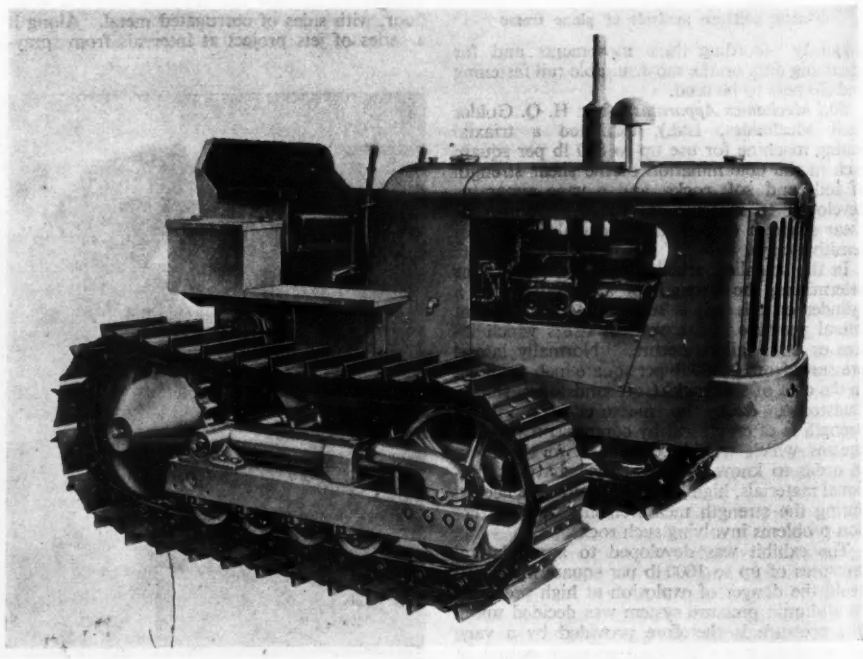


Fig. 7—Crawler tractor for heavy agricultural work or medium-scale earth-moving operations. Its four-cylinder diesel engine develops 48 b.h.p. at 1600 r.p.m.

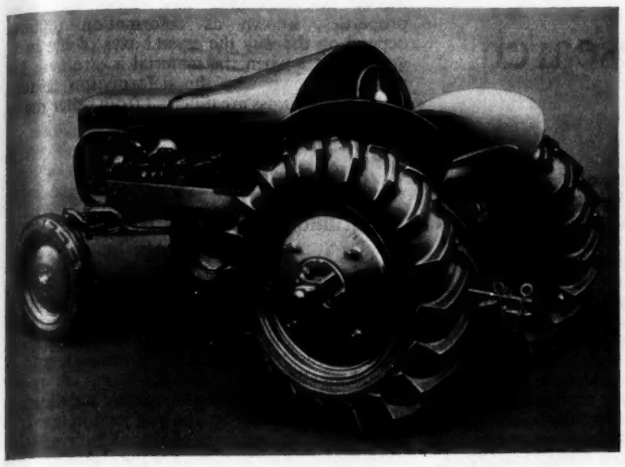


Fig. 9—Light tractor as designed for orchard and market garden work

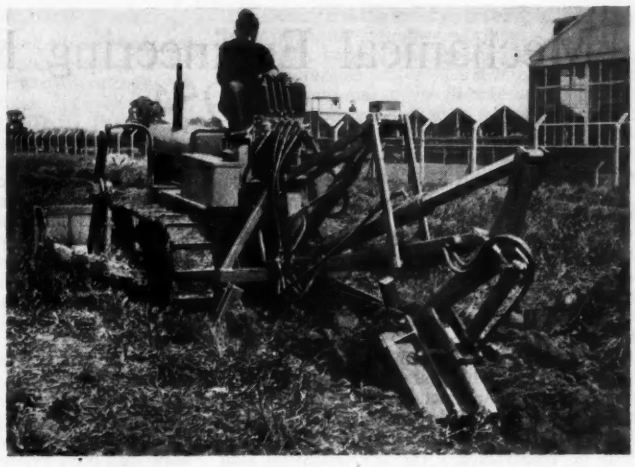


Fig. 10—Trench digger mounted on crawler tractor. The digger is equipped with a 24in bucket

speeds are from 1·31 to 5·15 m.p.h. and the two reverse speeds are 1·01 and 2·13 m.p.h., and in first gear the tractor can exert a maximum drawbar pull of 12,000 lb.

The engine and transmission casings form a strong chassis which is built independently of the track unit. The tracks and track rollers are identical with those fitted to the Fowler 40 b.h.p. diesel crawler tractor. The gauge from centre to centre of tracks is 56in, the length of the tracks on the ground being 60½in. There are thirty track shoes, 14in wide, on each side, and the area of ground contact is 1687 square inches. The tractor is steered by controlled differential, with hand levers operated on each side of the steering unit. Provision has been made for fitting various items of ancillary equipment to the tractor, including a central power take-off shaft, a rear-mounted belt pulley, a hydraulically operated bulldozer, and a heavy-duty haulage winch.

Among the other tractors shown by the Marshall-Fowler organisation there is the production version of the "M.P.6" wheeled diesel tractor. A brief description of the prototype of this machine was printed in our issue of November 12, 1954. The tractor is fitted with a Leyland six-cylinder, four-stroke diesel engine, which develops 70 b.h.p. at 1700 r.p.m. There is provision for six forward speeds between 1·89 and 14·6 m.p.h. and two reverse speeds of 2·78 and 4·46 m.p.h. This tractor has been designed for work in the cultivation of large areas of land, but its power and manœuvrability make it suitable also for many industrial uses.

A new version of the "President" four-wheeled tractor is exhibited by Brockhouse Engineering (Southport), Ltd. It is known as the "Orchard" model (Fig. 9), and as its name implies it has been designed specially to meet the requirements of fruit growers. Basically, the tractor is similar to the original "President"; it has a four-cylinder engine, developing 8 h.p. to 10 h.p., which is supplied for either petrol or tractor vaporising oil. There are three forward speeds of 1·8, 3·4 and 8·3 m.p.h., and a reverse speed of 2·9 m.p.h. The "Orchard" model differs from the orthodox "President" in that its overall height is 13in less. The angle of the steering column has been changed, and all protruding parts, such as the exhaust pipe, and air cleaner have been repositioned to give a clear bonnet top. In addition, as may be noted in our illustration, a detachable cowl is fitted which enables overhanging foliage to be brushed aside by the tractor as it moves forward. The overall width of this tractor is 5ft 6in and its rear wheel track is adjustable from 3ft 4in to 6ft. Another point about the design of the "Orchard" is that the under-sump clearance and the mounted implement linkages are the same as those of the "President."

Several examples of the variety of agricultural machinery made by Bamfords, Ltd., Uttoxeter, Staffs, are exhibited at Nottingham. One new device is a wire-tying unit which the firm has produced for its "BL60" automatic pick-up baler, and which is interchangeable with the twine-tying apparatus normally incorporated in that machine. This wire tyer works on the twisting principle, there being only one twist on each band. This year, Bamfords, Ltd., has introduced another new automatic pick-up baler for hay or straw. It has a pick-up width of 48in and has been designed with the requirements of smaller farms in mind. This baler, the "B48," is being built for oil engine drive, as shown in Fig. 11, or for operation from a tractor's power take-off. The makers claim that the baler has the smallest practicable number of moving parts, chain drives are reduced to the minimum, and the only vee belt drive on the model illustrated is that from the engine to the flywheel. The pick-up drum is spring counter-balanced, enabling it to adjust itself easily to undulating ground, and the action of the sweep fork and auger is such that the crop is kept moving steadily to the baling chamber. The baling chamber is equipped with an automatic tensioning device, and the crop is tightly held by dogs at top and bottom, while the plunger returns for the next charge. The cutting knives are adjustable. The bale-tying device is similar to that fitted to the firm's larger automatic baler; the needles are controlled by a trip clutch, and the twine fingers swing backward during the actual tying operation and provide just enough slack in the twine to form the knot. Throughout the machine there are adequate safety devices, there being an overload clutch for the main flywheel and an adjustable clutch to the auxiliary drives. The machine is stated to be capable of handling up to 7 tons an hour, forming rectangular bales 18in wide by 14in deep, in lengths of 18in, 30in, 36in or 42in.

In articles dealing with previous agricultural machinery exhibitions we have described the Howard "Rotavator" system of cultivation, the implements for which are manufactured by Rotary Hoes, Ltd., Horndon, Essex. At Nottingham, there is shown for the first time a new trailing "Rotavator" (model "H") with a working width of 5ft 10in and suitable for operation by the power take-off of a tractor in the 45 to 65 b.h.p. range. This firm is also exhibiting the "Platypus" crawler tractor, which is manufactured by its associate, the Platypus Tractor Company, Ltd., Basildon, Essex. One model of this tractor, the "PD2," has been adapted for operating the "Dinkum" digger, made by Whitlock Brothers, Ltd., and described in THE ENGINEER of December 19, 1952. The arrangement is illustrated in Fig. 10, from which it will be noted that an angledozer is fitted at the front of the tractor. The Platypus "PD2" is powered by a Perkins "P4" diesel engine.

(To be continued)

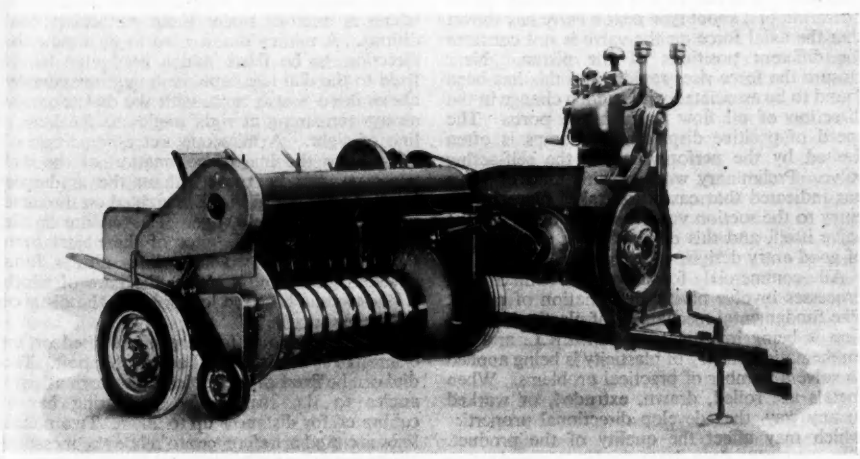


Fig. 11—Automatic pick-up baler with a working width of 48in and a capacity of up to 7 tons an hour

SYMPOSIUM ON THE CHLORINATION OF WATER.—The Society for Water Treatment and Examination will be holding its autumn meeting for 1955 at Newcastle upon Tyne, between Wednesday, September 21st, and Friday, September 23rd. On the evening of September 21st a symposium on the "Chlorination of Water," to commemorate the jubilee of chlorination of water at Lincoln in 1905, will be held at the Ethel William Hall, King's College, at 8 p.m. Those taking part in the symposium will be D. B. Byles (who took an active part in the chlorination at Lincoln fifty years ago), Dr. G. Carter, Dr. A. T. Palin, A. Waddington, and E. A. Whitlock. On Thursday, September 22nd, the following three papers will be presented to the Society:—"The Ecology of Algæ and Waterworks Practice," by Dr. J. W. G. Lund; "A Comparison of English and American Water Treatment Practice," by P. C. G. Isaac; "Legal Aspects of River Pollution with Special Reference to Water Quality," by S. C. Barrett. Visits to local water treatment works have been arranged for September 22nd and 23rd.

Mechanical Engineering Research, 1954

THE annual report for 1954 of the Mechanical Engineering Research Board was published recently.*

The work carried out in the laboratory at East Kilbride, Glasgow, during 1954 is reviewed in the report of the board and described in more detail in the report of the director of mechanical engineering research. The hydraulic machinery building of the laboratory at East Kilbride, Glasgow, was occupied at the end of the year and work started on the heat transfer building and the mechanisms and metrology building. Under the five-year plan of the department a plasticity laboratory and an administration building will also be constructed. The non-industrial staff of the laboratory increased by over 25 per cent during the year and now totals 226 ; it is hoped to employ a further 140 persons by 1959.

Typical Research Activities

Little has been known until recently about the way fatigue cracks form and grow. It is usually assumed that once a crack has formed it will spread rapidly due to the high stress concentration set up at the tip of the crack. Work at the laboratory has shown that cracks in vee-notched specimens of an aluminium alloy formed at low applied stresses grow to their maximum depth in 100,000 cycles ; no further growth of the cracks occurs with repeated loading up to 30,000,000 cycles. Investigation of the length of cracks formed under different nominal stresses suggests that the maximum length of non-propagating crack can be predicted from the stress distribution near the notch. It seems that for each material there is a limiting maximum stress concentration factor which is determined by the ratio of the stress needed to start fatigue cracks to that required to make them grow.

At the request of a firm of razor blade manufacturers the laboratory has developed a simple instrument which measures the width of double-edged razor blades and checks whether the slots are central between the edges. The firm had previously used a dial indicator for the purpose but this damaged the edges of several thousand blades daily. The inexpensive pneumatic gauge produced by the laboratory makes the measurements without touching the edge of the blade. The instrument consists of two measuring heads connected to a pneumatic system. Each head has two orifices one above the other. To the lower one air at constant pressure is supplied, the air stream passing from the orifice across an air gap to the upper orifice, which is connected to a bellows type pressure gauge. The blade obstructs the air flow across the gap and alters the pressure reading. As the reading is dependent on the degree of obstruction the two half-widths are indicated directly on two gauges. To provide a continuous check on blade width during production, without removing blades for gauging, a similar instrument which fits on to the grinding machine has been produced and is now being tested.

Methods of promoting dropwise condensation in steam condensers have been investigated at the request of the laboratory. The importance of dropwise condensation lies in the increased efficiency of the condenser when the steam can be made to condense in drops, rather than as a film on the condensing surface. If continuous dropwise condensation could be maintained in commercial condensing plant the capacity of existing plant could be increased, and the capital cost of new plant could be considerably reduced because smaller condensers would be required. Work carried out under an extra-departmental contract by the University of London (Queen Mary College) has resulted in the synthesis of about a hundred substances which promote dropwise condensation and which form chemical bonds with brass or copper, the materials usually used for condensing surfaces. Following laboratory tests, in which certain of the compounds functioned satisfactorily for as long as five months, tests under working conditions are now being carried out on the condenser tubes of a small cross-channel steamer and in a power station.

The complex-stress, high-temperature creep laboratory is now in full use and the behaviour of power plant steels under cyclic conditions of stress and temperature is being studied. The effects of cycles of plastic strain on gas turbine rims at their normal working temperatures have also been examined. Until recently, creep under complex-stress systems at high temperatures has been measured under steady stress conditions. In a number of practical cases, however, the stress varies and a particular instance of this is relaxation where stress falls with time, while the total strain remains constant. Examples of components in which creep takes place under relaxation conditions are high-temperature pipe flanges and cooled discs in aircraft gas turbines. A combined tension and torsion machine has been constructed to provide the basic data for the design of this kind of component, and relaxation tests under combined stresses are being carried out on a range of engineering materials, including a 0·17 per cent carbon steel, a Nimonic alloy, aluminium alloy RR 59, a 98 per cent pure magnesium alloy, and a commercially pure copper.

The laboratory continues to study problems of lubrication and wear and a laboratory using radioactive isotopes in examining wear processes is now in use. A method of visual examination of the way in which lubricants behave is being used to study the extent to which an oil film develops in journal bearings. Transparent bearings of " Perspex " or glass are used and the oil film is made to fluoresce by irradiation with ultra-violet light. It has been found that the inlet film is incomplete even with high inlet pressures : this is contrary to the usual assumption in theoretical analyses that the inlet film is complete. The technique of using transparent bearings has opened up a wide field for studying oil flow through journal and thrust bearings. To study the effect of variations of temperature at different points in bearings, a method of recording continuously the temperature of different parts of a bearing under working conditions has been devised. In a bush of 2in bore 100 thermo-couples are inserted in a radial and circumferential array of holes. The method will be used to provide data from which to calculate frictional losses.

The performance of oil-hydraulic systems is now being investigated in the laboratory. Existing design data are inadequate for the higher speeds and working pressures now required and particular attention is being paid to basic components such as pumps and valves. Study of the operation of a spool type piston valve has shown that the axial force on the valve is not constant for different positions of the piston. Near closure the force rises rapidly and this has been found to be associated with sudden change in the direction of oil flow through the ports. The speed of positive displacement pumps is often limited by the performance of the self-acting valve. Preliminary work on this kind of valve has indicated that cavitation takes place in the entry to the suction valve before it occurs in the valve itself, and this emphasises the importance of good entry design.

All commercial formation and machining processes involve plastic deformation of metals. The fundamental mechanism of plastic deformation is being investigated at M.E.R.L. and the mathematical theory of plasticity is being applied to solve a number of practical problems. When metals are rolled, drawn, extruded, or worked in any way, they develop directional properties which may affect the quality of the product. For example, deep-drawn cups often develop " ears " which have to be machined off. The theory has explained how these directional properties, known as deformation textures, depend on the way the crystal axes of the metal grains rotate when the material is strained, and has also shown why the deformation textures developed in brass are different from other metals of the same crystal lattice structure.

* H.M. Stationery Office. Price 3s.

Continuous Casting Machines for Zinc Ingots

INGOT casting machines in many sizes have been made for a number of years by Sheppard and Sons, Ltd., Bridgend, for the continuous casting of non-ferrous ingots in aluminium, copper, brass, bronze, lead, gunmetal, and of special quality irons and pig iron. A recent communication from this firm mentions a problem that arose in the production by continuous casting machines of zinc slabs in which it was essential that the surface of the slabs should be free of ripple and shudder marks, and be of uniform quality. The usual drives fitted to the firm's continuous casting machines, through multi-sided drums or large centre-link chain wheels, made it impossible to achieve the smooth transmission essential to produce slabs to the particular requirements. For this reason a new design of drive was developed.

The principle of this development depends on the fact that with the normal drive head of link mechanisms chordal action in some degree occurs, and it is this chordal action which caused ripples on the surface of the ingots. The machine developed to overcome these conditions has its drive unit mounted beneath on a separate foundation, and the power is transmitted to the returning empty mould chains by a series of uniform pitched steel dogs. These dogs are so arranged and mounted on a " caterpillar " chain as to transmit only a uniform horizontal motion to the main mould chain.

In a typical ingot casting machine of this kind the motor drive is transmitted through a thermionic-valve-controlled dynamic coupling giving stepless speed control to a worm reduction unit driving the caterpillar chain. With it complete control over speed is obtained without direct metallic connection between the driving unit and the ingot producing machine itself, making possible the production of smooth well finished ingots. The first machine built to the new design was supplied to the Consolidated Mining and Smelting Company in British Columbia.

Instrument for Shaft Surveying

WE are informed by the National Coal Board that a device for shaft surveying has been developed by Mr. J. E. Bellis, the chief surveyor of No. 3 area of the North Eastern Division of the Board. The object of a shaft survey, it is pointed out, is to relate the shaft walls and equipment at the several horizons. The aim of the new system is to obviate direct measurement of distance which is onerous under these particular conditions. A mining dial is used to determine the direction to be fixed, and a graduated bar is fixed to the dial telescope mounting immediately above it, so that it turns with the dial telescope always remaining at right angles to the latter's line of sight. A telescope, set at an angle of 1 in 20 to the line of collimation of the dial telescope, can be moved along the graduated bar and adjusted so that it is sighted on the same point as the dial telescope. The reading on the bar then gives the distance of the object from the dial (i.e. the two sight lines always form similar right-angled triangle, the base of which is one-twentieth of the longer side—the distance to be measured).

In practice the instrument is mounted on an extensible strut, fixed right across the shaft. The dial can be fixed at any point on an arm at right angles to the strut. The measuring bar is calibrated for distances up to 200in. Two plumb lines are used as references to relate the measurements made at different levels and instrument settings.

Ten-Year Forecast of Electricity Generation in Britain

In a paper presented at the British Electrical Power Convention at Brighton on June 28th, Mr. J. Eccles, deputy chairman of the Central Electricity Authority, gave a ten-year forecast of the development of electricity generation in Britain. His paper began with a brief historical review of the electricity supply industry since 1920, *showing the rate of increase of demand. Extrapolating forward, it was shown that the expected installed generating capacity to meet the demand in* 1965 *would be* 36,000*MW of which* 1500*MW to* 2000*MW would be nuclear power plant. The rest of the paper dealt with the kind of generating plant likely to be installed: abstracts are given here.*

BRITISH plans for increasing industrial productivity are based upon the assumption that the coal mined in this country will be insufficient to meet the nation's fuel requirements and maintain coal exports at the desired rate. The precise amount of the overall shortfall in each year is not of first importance to our immediate discussion but it is of importance to know the amount by which the coal available for electricity purposes will fall short of requirements. Since the electricity supply industry is such a flexible instrument, it would be possible to maintain the coal supply to other industries by causing a disproportionate amount of electricity to be produced from other fuels. This is one illustration of the value of this industry in maintaining and expanding industrial productivity in face of a coal shortage but it is important to state and maintain that the method should not be used to prejudice the competitive position of electricity.

In the year ended March 31, 1955, the British Electricity Authority used 2,200,000 tons of imported coal. The Ministry of Fuel and Power estimate that there will be a progressively widening gap between available home-produced coal and that needed for actual electricity consumption. Indeed, it is thought that the home coal available for electricity may never exceed a ceiling of about 60,000,000 tons per annum and that our further requirements must be met by imported fossil fuels or by nuclear fuel.

Since the technology of electricity production differs little whether the fuel be coal or oil, the relative consumption of these two fuels does not affect the size and type of generating plant to be installed. If, however, as the estimates show, the capital cost per kilowatt of the early nuclear power stations will be relatively high and the running cost relatively low, the average cost per unit of electricity produced would be a minimum if the nuclear power plants supply the base load.

The prospect of the injection of a large block of nuclear power plant into a forward programme, therefore, raises questions as to what is the most economical size and type of conventional generating unit and station to supply the remainder of the load. Despite every effort to improve the system load factor, it would seem that the bulk of the future conventional plant must be capable of single and two shift working and this fact alone may place an upper limit on size of set and on the steam temperature and pressure to be used. Perhaps the right answer will be for manufacturers to make all sets suitable for frequent starting and stopping. This may also be important from another aspect because if, in future, the capital cost per kilowatt of nuclear stations approaches that of the conventional stations then only the highest thermal performance of the latter will enable them to hold their own as economical producers of electricity even at low load factors.

A further likely development of limited application in this country is that of pumped storage. Nuclear power plants having a low fuel cost could provide energy for pumping water into elevated storage reservoirs at off-peak periods and this water could be used to generate electricity at peak periods. The effect would be to maintain a high operating load factor on the nuclear plants and, in suitable conditions, provide relatively cheap peak-load power. The controllability of pumped storage installations is of a very high order and the combination should provide a very flexible power system.

CONVENTIONAL GENERATING PLANT

The bulk of the generating plant which has been installed since 1948 has been of either 30MW or 60MW rating. These two ratings, with associated steam conditions of 600 p.s.i., 850 deg. Fah. and 900 p.s.i., 900 deg. Fah. respectively, were adopted as standards in the early post-war period to rationalise the production of heavy electrical plant and speed up its manufacture. The 60MW unit was the first true post-war development and the associated steam conditions, although by no means the highest employed in this country, were well above those in general use at that time. Some 118 of these units have now been installed or ordered.

Post-war developments in boiler design have enabled boiler availability to be improved to the point where the installation of spare boiler capacity can no longer be justified on economic grounds.

The elimination of spare boiler capacity led naturally to the conception of the unit system, in which there is no interconnection between adjacent boilers or turbines. This system has now become general and enables appreciable savings to be made on pipework and valves. Admittedly, some reduction in availability must result from the loss of the facility to use any boiler with any set but, as against this, the simplification of pipework, elimination of headers and reduction in the number of valves reduce the risk of breakdowns.

On the turbine side there was the decision to break away from the then current practice of designing the machine for the most efficient performance at 80 per cent of maximum continuous rating. This made possible the elimination of overload belts and simplified the design of the cylinder castings, without reducing the efficiency of the set. Difficulties that have since been experienced in obtaining sound castings, even of the simplified design, confirm that in this respect this decision was a wise one.

So far as boilers are concerned, it is only necessary to compare the modern pulverised fuel fired boiler with an earlier stoker fired unit to see the great strides that have been made in simplification of design. The introduction of liberally rated furnaces with bare water tubes from top to bottom without intermediate headers, the elimination of multi-pass baffling, and the use of more widely spaced convection surface tubes have played a major part in minimising rates of fouling of heating surfaces. Mechanical reliability has been improved by the widespread use of welding. Stub nipples on headers with site welding to tubes reduces the need for hand-hole fittings and, where these are still necessary, seal welding or full welding avoids the risk of leakage inherent in mechanical joints subjected to high pressure.

The elimination of steam-driven boiler feed pumps and auxiliary oil pumps was another development aimed at improving the availability of the unit and on later plant designed to operate at higher steam conditions this trend towards the elimination of steam-driven auxiliaries has been carried even further.

To those who are intimately concerned with the great strides that have been made since the 60MW unit was developed, all this is history, but it is worth while recalling how much has been accomplished in the way of simplification, and remembering its value when developing designs for more advanced steam conditions.

The economic necessity to conserve fuel was (and is) of such vital importance to the nation and to the supply industry that the Authority have always held that they must take normal commercial risks and press on with the largest sets of the highest economic performance that manufacturers can produce. Therefore, when the Regulation limiting sizes to 30MW and 60MW was revoked in 1950, the Authority issued specifications, on which they had been working for some time, for units to operate on more advanced steam conditions. Eight 60MW units and ten 100MW units, all to operate at steam conditions of 1500 p.s.i., 1050 deg. Fah., have been ordered as a first instalment of this new development.

The adoption of the unit principle—one boiler, one turbine—led to a reconsideration of reheating as a means of further improving the economy of generation. Reheating was no new thing in this country but the unit system offered the possibility of greatly simplified working.

The first large reheating unit plant under the new programme was of 100MW capacity with steam conditions at the turbine stop valve of 1500 p.s.i., 975 deg. Fah. and a reheat temperature of 950 deg. Fah. This unit has not yet been commissioned, but there is little doubt that it will be economically justified. Four reheat units of this size are on order.

In the design of large steam turbines one of the major developments is that of the last few rows of blades. These blades must be of complex profile to enable the maximum amount of work to be extracted from steam at all radii and yet be sufficiently strong to withstand the enormous centrifugal and bending forces arising from their high rotational velocity. In common with all other blades they must be so designed and assembled that their frequencies of natural vibration lie outside the range of operating conditions. The design of such blades is therefore a major undertaking and in developing a range of turbine sizes it is desirable to reduce to a minimum the number of blade sizes and profiles that will be required.

Since reheating reduces the amount of steam consumed by the turbine for each unit generated it was possible to use the blades developed for the 100MW straight (non-reheat) cycle to produce a greater output in reheating machines. Accordingly it was decided to introduce the 120MW unit with initial steam conditions of 1500 p.s.i., 1000 deg. Fah., with reheating to 1000 deg, Fah. ; the associated boiler rating being 860,000 lb of steam per hour. Eight of these units have already been ordered and they are steadily replacing the standard 60MW units in current programmes.

The design of the 120MW units exhibits no fundamental change from that for 60MW, but certain trends are observable. As the size of unit increases the ratio between the volume of the furnace and the surface area of the walls increases and the furnace volume, therefore, tends to become uneconomically large for the required cooling surface. Furthermore, the cooling effect of the water walls is felt less and less towards the centre of the furnace and consequently high gas temperatures tend to be produced at the furnace outlet at this point. This difficulty can be overcome by the introduction of a division wall of water cooled tubes extending either partially or completely across the centre of the furnace. Corner firing makes this impracticable, however, and the various boiler designs offered for the 120MW units differ in this respect, some being completely undivided, others partially or fully divided.

With higher steam conditions and with the use of reheating, the amount of heat absorbed in superheating the steam increases relative to that required to evaporate the feed water. It therefore becomes more difficult to accommodate the whole of the superheating surface in the convection zone of the boiler and there is a trend towards the use of some radiant surface for superheaters and reheaters. The use of radiant surface for this purpose tends to flatten the boiler temperature characteristic, and thus to reduce the rate at which the steam temperature falls off with load. Within limits this may be no disadvantage since, with a unit boiler-turbine combination operating under two-shift conditions, the temperature of the steam delivered by the boiler after an overnight shut-down usually tends to be too low in relation to the temperature of the turbine.

The main trends in turbine design are towards the use of double casings for the high pressure cylinders and solid couplings in place of the flexible type between rotors. The advantage of the double-casing design of cylinder is that, by drawing steam at an intermediate pressure through the space between the inner and outer casings, the pressure drop is split between the two casings and each can therefore be made of lighter construction, thus permitting more rapid warming of the cylinder during starting without serious distortion. The mechanical construction of the cylinder is, of necessity, more complex and British manufacturers appear to be fairly evenly divided in their opinions as to the necessity of this kind of construction for 120MW machines.

With increasing outputs the torque transmitted by the turbine couplings increases and the accommodation of thermal expansion, which the flexible coupling is intended to permit, may be prevented by locking of the mating surfaces. This trouble, with consequent failure of thrust bearings, has already been experienced on some of the earlier designs of 60MW machines, and solid couplings are preferred where large torques have to be transmitted.

The trend towards the elimination of steam-driven auxiliaries has, as previously mentioned, been continued on these units. The use of steam-operated air ejectors has been discontinued and motor-driven air pumps are now specified.

As in the case of the 60MW units, the generators are cooled by hydrogen, the trend in this respect being towards the use of higher pressures. The 60MW units (originally using hydrogen at ½ p.s.i.) are now specified to operate at 15 p.s.i. A pressure of 30 p.s.i. is now being specified for the 120MW units. The higher pressure enables the physical size of the generator to be reduced, and the consequent saving in capital cost outweighs the small reduction in efficiency that results.

With the development of suitable starting techniques all 120MW units are expected to be capable of operating under two-shift conditions.

The temperature of the steam delivered by the boiler in relation to that of the casing metal is an important factor in the rapid starting of a turbine after an overnight shut-down. It is thought that the designs which are now being developed will provide sufficient flexibility of temperature control to enable requirements in this respect to be met, but a programme of experimental work on certain selected sets already in commission has been put in hand to provide more data on this problem.

With increasing steam pressures and temperatures the metal thicknesses required for turbine casings and steam piping become greater and the problem of thermal stressing due to temperature gradients during warming up becomes more acute. The use of double casings alleviates the situation on turbine cylinders, but steam chests and steam piping still present a problem. Austenitic steels, with their greater creep strength at high temperature, enable metal thicknesses to be reduced but, owing to their higher coefficients of expansion and lower thermal conductivities, do not necessarily lead to lower thermal stresses.

As soon as the 120MW reheat programme was under way, the Authority turned their attention to the next logical step in size and steam conditions which would secure further economies. Bearing in mind the value of standard components in keeping down development costs, the limitation on the safe peripheral speed of the electrical rotor and the problems of evaporation as the " Critical Pressure " (3200 p.s.i.) is approached, a unit size of 200MW with steam conditions of 2350 p.s.i. and 1050 deg. Fah. at the turbine stop valve and a reheat temperature of 1000 deg. Fah. was selected. Opportunity to quote for single-shaft (tandem) or two-shaft (cross compound) sets was given and the tandem design has been chosen for the first three sets to be installed at High Marnham in 1959 and 1960.

The boiler rating for this unit is 1,400,000 lb per hour, the steam pressure at the boiler stop valve being 2450 p.s.i. The boiler will be of the twin-furnace design with assisted circulation but otherwise will be a normal development from the 120MW reheat unit.

The alternator stator has been kept within road transport limits by employing direct cooling of the stator conductors and the diameter of the electrical rotor has likewise been kept to a safe limit for operation at 3000 r.p.m. by direct cooling of the rotor conductors. The cooling medium throughout is hydrogen. The pressure of the general cooling circuit is 30 p.s.i. and the conductor coolant is led into and out of the conductors by special means. With direct cooling it is possible to obtain a very much greater rating from a given alternator frame size and consequently the cost per megawatt should be substantially less. Against this capital saving one must place the cost of the additional losses due to the much higher current density in the conductors.

The following table shows the optimum efficiencies expected from the various ratings of generating plant described herein.

Thermal Efficiencies

Turbo-generator, C.M.R.	Pressure at turbine S.V.	Temperature at turbine S.V.	Reheat temperature	Expected test efficiency on basis of kWh generated, vacuum 28·9in
MW	P.s.i.g.	Deg. Fah.	Deg. Fah.	Per cent
30	600	850	—	29·3
60	900	900	—	31·9
60	1500	1050	—	33·7
100	1500	1050	—	34·5
100	1500	975	950	35·4
120	1500	1000	1000	35·8
200	2350	1050	1000	37·6

Studies in the design and application of still larger units operating upon more advanced steam conditions are in hand. The next step in steam pressure would be into the supercritical stage, perhaps in the region of 4000/5000 p.s.i. In such studies it is necessary to make a close assessment of all the relevant factors and circumstances, taking them one at a time, and in combination, if the best result is to be achieved. For instance, increased rating normally produces a reduction in cost per kilowatt whilst increased steam pressure and temperature tends to make the plant more expensive. Furthermore, higher steam conditions give a higher thermal efficiency and the value of this thermal gain depends upon the capital cost of achieving it, upon the price of fuel, and upon the load factor at which the plant is to run throughout its useful life. Special cooling arrangements reduce the efficiency of the alternator though they are indispensable if one is to have safe operation of very large machines. These are some of the matters which have to be taken into account in planning a generating plant programme for a long time ahead.

The forward studies now being undertaken are enlivened by the imminent prospect of industrial nuclear power on a substantial scale but at a somewhat speculative cost. If nuclear fuel is readily available at a lower cost per kilowatt-hour than that of coal, then clearly it would be in the interest of the supply industry to operate the nuclear power stations at the highest practicable load factor. Any improvement in design which reduces the capital cost of these stations, without increasing the fuel cost, will be pure gain. It is believed that the fuel cost per unit in nuclear power stations will be less than that of even the most advanced stations burning coal or oil and hence the problem resolves itself into how much nuclear fuel will be available, what will be the capital cost of the new stations and what is the right balance between capital cost and thermal efficiency of the coal and oil fired stations to produce the most economical result at their prevailing load factors.

It is not possible to go into further detail here but clearly size and steam conditions are in the melting pot. One thing is certain, and that is that all sets must be capable of two-shift and single-shift working. Studies are also being made of the various gas turbine cycles, including those which operate on gas turbine principles, using steam as the working fluid.

Pumped Storage

The Central Electricity Authority is at present seeking powers to authorise the construction of a pumped storage scheme near Blaenau Ffestiniog in North Wales. The unit installation will consist essentially of a hydro-electric turbo-generator and a motor driven pump, both of which are connected into a pipeline and tunnel joining a high level and a low level reservoir. Water will be pumped from the lower to the upper reservoir during the night when high efficiency generating plant is available to supply power for this purpose. During daytime peak hours the water will be allowed to flow from the upper to the lower reservoir, through the turbo-generator, thus avoiding the necessity to use corresponding capacity of inefficient thermal plant.

At Ffestiniog suitable reservoir sites are available less than a mile apart with a difference in head of approximately 1000ft. The plant capacity proposed is 300MW, probably in six 50MW units and the scheme will have an output of some 300,000,000kWh per annum. The scheme will be connected into the super-grid system by means of a 275kV line to Carrington via Hawarden. Subject to early Parliamentary approval, the first 100MW will come into operation for the winter of 1961/62, the second 100MW for 1962/63 and the final 100MW for 1963/64.

The main advantages of this scheme are : a substantial saving in capital cost as compared with an equivalent thermal generating station, and an even greater saving in the annual costs of electricity production, owing to the much lower annual capital charges on the installation arising from lower capital cost and longer life. The electricity used for pumping will be generated during the night at the incremental cost of the base load plant. The scheme will also provide readily available standby plant capacity when its output is not required to meet the winter peak load, relieving an equivalent capacity of steam plant from " hot standby " duties with the consequent saving in fuel costs. This pumped storage scheme therefore offers an economical means of providing readily available standby plant capacity. The Ffestiniog sets will be much more flexible in operation than normal steam plant and will thus assist in meeting sudden changes of load and in the control of frequency. It is estimated that these sets will be capable of being brought to full load generation from standstill in approximately five minutes. Similarly, should an emergency arise on the system at night during the pumping period, each pump could be completely shut down in five minutes and the turbines brought on load in the same order of time. A further important advantage of this pumped storage station is that considerably fewer operating staff will be required than for steam stations of comparable capacity.

It is an attractive method of providing peak-load power on a system that is mainly supplied by thermal plants of varying ages and efficiencies. On a system supplied by nuclear power stations it could be even more attractive.

Nuclear Power Programme

As indicated earlier, the native coal that is likely to be available for electricity generation will be insufficient to meet the estimated requirements. Another fuel will have to be used and the Government have decided that the prospects of nuclear power are sufficiently promising to enable them to sanction the development programme set out in the White Paper Cmd. 9389 of February, 1955.

This programme has been made possible by the tremendous success of the Atomic Energy Division of the Ministry of Supply and, later, the United Kingdom Atomic Energy Authority, in their researches at Harwell and the application of the results by the Industrial Section at Risley. Since 1945, when the opportunities for practical collaboration with the United States were first restricted, British physicists and engineers have been working unceasingly on these problems. During that period, they have built four nuclear reactors, two at Harwell and two at Windscale, and are in process of completing the first nuclear power station for the production of electricity at Calder Hall. Engineers of the Central Electricity Authority have been assisting in this work.

A good deal has been said and written about the harnessing of nuclear energy but, perhaps, it might be useful if I were to repeat some of it here.

Uranium-235 is the only element found in nature that is capable of spontaneous fission and, of the total natural uranium, only one part in 140 is of this very valuable kind. The remaining uranium of atomic weight 238 and thorium of atomic weight 232, although not themselves fissile, are capable of being transmuted into elements which are fissile ; they are, therefore, known as fertile elements.

The Calder Hall plant employs natural uranium in sufficient quantity and so arranged that the 235 component can establish a chain reaction in which the neutrons from each fission of a U-235 atom can be persuaded to cause the fission of another U-235 atom or to enter an atom of U-238 and, by a double reaction, transmute it into plutonium Pu-239. There are two or three neutrons per fission and one of these must cause another U-235 fission to keep the process going whilst the remaining one or two are generally available to produce plutonium in so far as they are not lost in the process. There is thus a double process proceeding

simultaneously. Atoms of U-235 are breaking down causing other atoms of U-235 to follow suit and also causing atoms of U-238 to be transmuted into plutonium.

The significance of the U-238 plutonium reaction is that plutonium is a fissile material and in most respects can be used in the same way as the very scarce U-235.

A reactor of the Calder Hall type will thus consume U-235 and liberate heat whilst, at the same time, producing a partial replacement for the U-235 in plutonium-239. Plutonium being a separate chemical element can be separated from uranium and the fission products by chemical means and thus there can be made available a new fissile element never before found in nature. Uranium-235, being an isotope, cannot be separated from U-238 by chemical means and, hitherto, the main means of separation to produce concentrated fissile material, have been by gaseous diffusion and cyclotron.

Having obtained an additional supply of fissile material, it can be used to enrich natural uranium so that its fissile content becomes greater than one in 140 and this enriched material can be used in more advanced and more economical designs of reactor.

The early power reactors will be improved versions of the Calder Hall type using natural uranium and producing power and plutonium. The next stage will be to use more economical reactors requiring fuel enriched by the plutonium made in the early reactors. Reactors of the Calder Hall type will be gas cooled using a non-reactive gas such as CO_2 or helium, the heat so collected being used in a heat exchanger to produce steam. There may be a high and low pressure steam circuit, the high pressure being of the order of 400 p.s.i. with a small degree of superheat.

Two reactors, each with an electrical output of about 80MW may comprise the first station ; the construction of two such stations being scheduled to start in 1957 with a view to completion in 1960/61. They will be constructed to specifications prepared jointly by the Central Electricity Authority and the Atomic Energy Authority. Tenders will be invited by the C.E.A. from those industrial firms whose staff have been trained by the A.E.A. A contract will be let by the C.E.A. to the successful tenderer and, thereafter, the project will proceed on the normal contractual basis under the common supervision of the C.E.A. and A.E.A., with the latter having certain over-riding powers on questions of design. Other gas cooled reactors will be built in accordance with the programme.

When sufficient fissile material is available, it is expected that the design of liquid cooled reactors using normal water, heavy water, or other liquid, will be sufficiently advanced to permit of their construction for commercial purposes. They require enriched fuel but it is hoped that they will be of lower capital cost.

Beyond that the future offers almost unlimited scope to the reactor designer and, no doubt, economics will be the determining factor in a welter of alternative designs. The choice of coolants and moderators, the use of fuel in the solid or the fluid state and the technical and economic aspects of fast breeder reactors, such as that now being constructed at Dounreay, will engage the attention of designers for many years to come. Indeed, the whole subject projects itself into the unknown at so many points that, even if it were possible, it would be unwise to attempt to specify the precise line of future development. The prospect of using conventional fuel to superheat the steam coming from the heat exchanger should not be ruled out.

The programme envisages that, by 1965, some 1500MW to 2000MW of nuclear power plant will be in operation. The rate of commissioning at that time will, probably, be about 500MW per annum.

Conclusion

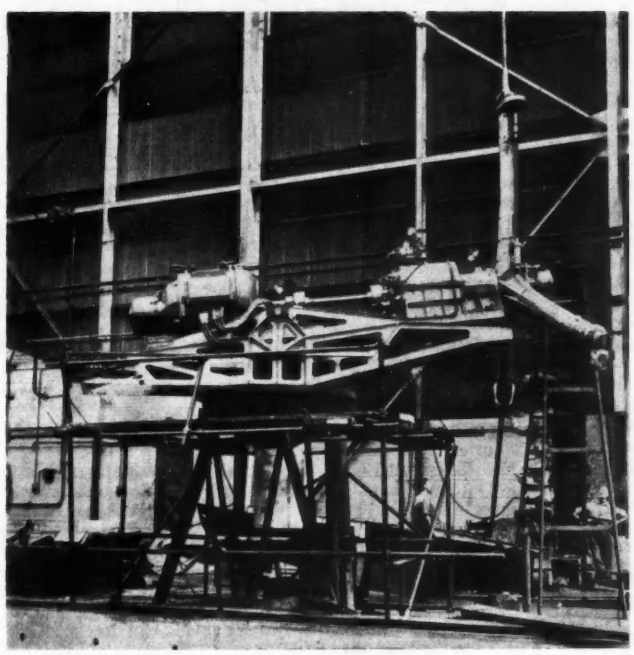
The estimated installed generating capacity to meet the demand for electricity in 1965 on the system previously administered by the British Electricity Authority is 36,000MW and, of this, it is expected that 1500/2000MW will be nuclear power plant. In addition, 2900MW of new plant will be required to replace that retired from service. The installed generating capacity at March 31, 1955, was 20,173MW. The average annual increase in capacity during the next ten years, therefore, must be 1875MW if the plant is to be there to carry the estimated load.

Under the programme there will be a gradual shift of emphasis from conventional to nuclear power plant—slow at first but accelerating later. If, however, the electricity supply industry is permitted to work up to an annual consumption of 60,000,000 tons of coal (50 per cent more than the 1954 consumption), there will be a substantial demand for conventional generating plant, for expansion and replacements, so long as this amount of coal is available at competitive cost.

Wind-Power Electric Generator

DETAILS have been released of a 100kW wind-powered generator built by John Brown and Co. (Clydebank), Ltd., for the North of Scotland Hydro-Electric Board. The machine has been erected on Costa Head, on the Orkney mainland, on a site which is 400ft above sea level. It is designed to feed into the local electricity network, which is normally supplied by diesel-driven generators.

When the contract was placed in 1949 the site on Costa Head was chosen because of the strength of the winds which prevail there, which sometimes exceeds 125 m.p.h., and the comparative absence of calm days. Generation of 100kW was to be achieved with a wind speed of 30 m.p.h. or above, with a reduced output for lesser speeds. This meant a blade circle of 60ft diameter, but later the "rated wind velocity" was increased to 35 m.p.h., allowing the blade circle diameter to be decreased to 50ft. The windmill was built for completely automatic operation, so that it should be possible to leave it entirely unattended for long periods. It consists of a three-bladed propeller and nacelle mounted on top of a steel tower at a height of 78ft above the ground. By means of a step-up gearbox the hub speed of 130 r.p.m. is increased to 750 r.p.m. for driving the electric generator. Yawing of the nacelle is obtained by mounting it on a pintle shaft and turning it by means of a bull ring and pinion driven at reduced speed by an electric motor. The arrangement is illustrated overleaf.



Trial erection of the gearbox, generator and hub assembly for 100kW wind-powered electric generator

The Tower.—Owing to the softness of the surface rocks an excavation to solid rock, 6ft 9in deep, was made for each of the three legs of the tower, and from the bottom of each excavation eight holes, 4in diameter by 6ft long, were drilled and 1in reinforcement bars grouted in position. A concrete block was then laid in the excavation and topped with a mild steel plate, through which the bars projected to act as foundation bolts. More concrete was poured to encase the tower legs to above ground level, and finally the holes were filled in with some of the excavated material.

The tower itself was constructed from angle sections, which were galvanised after fabrication. Its plan is triangular with 24ft sides at base and 7ft 10½in at 66ft level. From the ground to the bull gear the height is 71ft 6½in. Access is by means of a steel ladder with a resting platform at 32ft, and a servicing platform at 66ft. The total weight is some 7 tons.

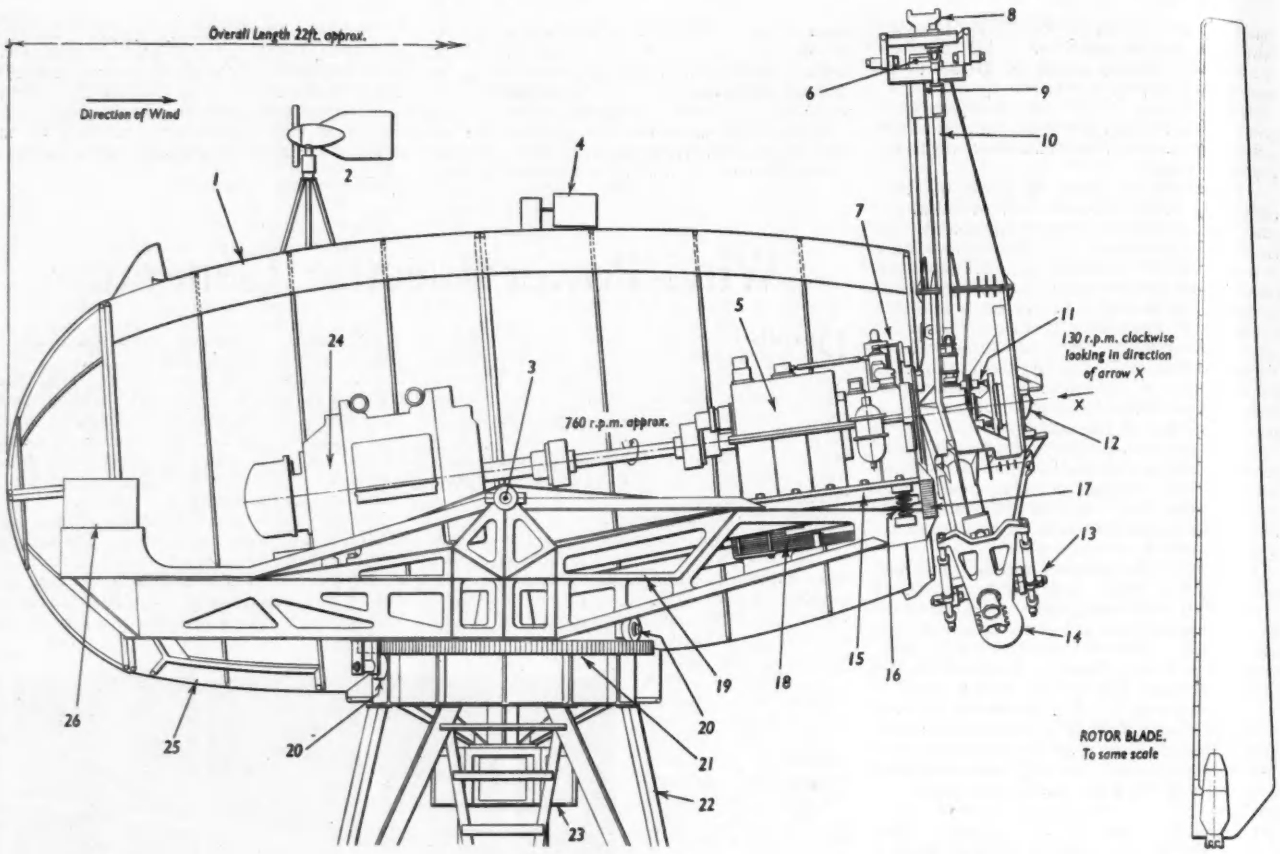
Nacelle.—The nacelle is of circular section with a maximum diameter of 9ft, and tapers from the centre towards each end. It is constructed from mild steel sheet on a tubular framework, and at the hemispherical windward end has a trapdoor with folding ladder, by which access is obtained from the platform. Overall length is approximately 19ft.

Rotor.—There are three blades and they are built to section NACA 0015, without twist. They are 17ft long and taper from 24in at the root to 11⅛in at the top. Each consists of a compressed laminated wood spar fitted with spruce ribs which are covered by $^{3}/_{32}$in mahogany plywood skin and protected with plastic.

The hub and arms are of fabricated mild steel reinforced with webs and gussets. The distance from the centre to the point where the blades are attached is 8ft. Inside each arm are fixed and moving pistons for varying the pitch of the blades. This is done hydraulically under the control of a servo-governor, the motion being transmitted through torque tubes and Hardy-Spicer couplings to quadrant boxes situated at the ends of the hub arms. Each blade root is attached by a quick-release fork to a universal joint, which allows the blade freedom to "cone" and "drag" at speed, thus avoiding excessive bending stresses at the roots. When the blade is at rest this joint is automatically locked so as to hold the blade fixed. The movement of the blades on their hinges is controlled by hydraulic dampers in order to prevent excessive vibration.

Gearbox and Generator.—All shafts of the gearbox run on ball or roller bearings. Helical gearwheels are used, together with a hydraulically operated brake and clutch. The housing is fabricated mild steel.

By means of the gearbox the hub speed is raised from 130 to 750 r.p.m. for driving the 100kW alternator, which generates at 415V, three phase, 50 c/s. It is a slip-ring induction machine, the output of which is stepped up to 11kV by a transformer situated at ground level. The gearbox and generator as well as the hub are shown, temporarily erected, in the above illustration.


Overall Length 22ft. approx.
Direction of Wind
760 r.p.m. approx.
130 r.p.m. clockwise looking in direction of arrow X
ROTOR BLADE.
To some scale

1. Nacelle.
2. Pilot windmill.
3. Rocking centre of floating bedplate.
4. Yawing vane.
5. Oil-operated gearbox, ratio approx. 6 : 1.
6. Internal hard rubber cushion.
7. Governor gear.
8. Blade attachment sleeve.
9. Centre of " coning and drag " hinge.
10. Pitch change torque tube.
11. Pitch change linkage.
12. Hydraulic cylinder.
13. Damper linkage.
14. Pitch change gearbox 7 : 9 step-up.
15. Floating bedplate.
16. Auxiliary coil springs.
17. Auxiliary transverse spring.
18. Main springs.
19. Fixed bedplate.
20. Rollers.
21. Bull gear.
22. Tower top.
23. Slipring assembly.
24. 100kW, 750 r.p.m., induction generator, totally enclosed fan cooled.
25. Access door.
26. Ballast tray and weights.

Sectional elevation of 100kW windmill installed at Costa Head, Orkney, for the North of Scotland Hydro-Electric Board

Yawing Gear and Bed-plates.—The windmill head is supported by the bull gear, a large and heavy steel casting fixed to the top of the tower. It forms the housing in which the pintle shaft, and hence the whole wind-head, rotates to keep the blades into the wind. The bull gear pitch circle diameter is 6ft 3in, and the pinion is driven by a 1 h.p., 960 r.p.m. motor through a 400 : 1 reduction gear and slipping coupling on the low-speed side.

The pintle shaft is a hollow steel casting measuring 4ft in length by 13½in outside diameter at the centre and tapering to 8in diameter at each end, with a wall thickness of 1in. It rotates in taper roller bearings in the bull gear, the bending stresses being relieved by four sets of rollers running on the flange of the bull gear.

A fixed bed-plate is firmly attached to the pintle shaft, on the windward end of which are mounted counterweights to balance the propeller. At the centre are situated the bearings for the floating bed-plate which carries the machinery itself and is supported at the front and sides by two sets of two quarter elliptic springs, two auxiliary coil springs, and one full elliptic transverse leaf spring.

Sliprings.—Six main sliprings of cupro-nickel are provided, three for the generator stator and three for the rotor, also twenty auxiliary rings and some smaller rings for testing purposes. All rings are supported on steatite insulators and have carbon bush collectors, four in parallel for the main rings and two in parallel for the auxiliaries.

Electrical Control Gear.—The electrical control gear is located in the control house at the foot of the tower and consists of main switches with the normal protective devices and relays of various kinds, with induction time relays where required.

Operation.—A small " pilot " windmill is mounted on top of the nacelle and serves to control the starting and stopping of the windmill. In order to prevent the machine being started by a gust in an otherwise calm period, it averages the wind speed over a number of minutes.

When starting, the clutch is disengaged and the generator is run up to speed on a motor, thereby starting the supply of lubricating oil and pressure oil for the various hydraulic controls. A brake on the rotor is released and the pitch control adjusts the pitch of the blades from the feathered position to that corresponding to the prevailing wind. The rotor then gathers speed under the control of the governor and at a predetermined rate which is independent of the wind. When the speeds of rotor and generator are correctly matched the clutch is engaged to connect them mechanically. By means of the electrical control gear operating on the governor the machine is then adjusted to carry full load. While normally this procedure is fully automatic, provision is made to carry it out by hand, if desired. Should a fault occur, the machine is automatically brought to rest and prevented from restarting until the fault has been rectified.

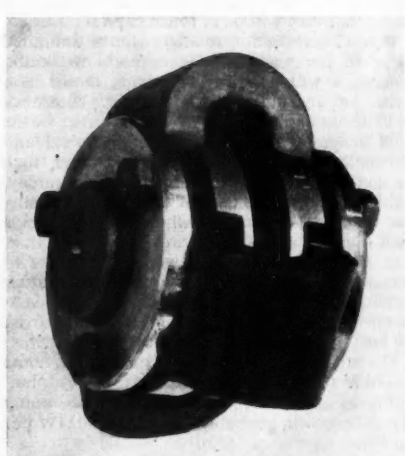
Flexible Couplings

A PHOTOGRAPH reproduced here shows the construction of the " Multicross " flexible coupling designed and now being made by the Owl Engineering Supplies, Ltd., of Doncaster, in a number of sizes. In these couplings flange ends keyed on to the driving and driven shafts have deep grooves machined in their outer faces. Torque is transmitted by U-shaped nylon reinforced rubber cushions, the leg of each of which registers in opposing flange grooves and is rigidly gripped by end retaining plates locked in position by means of bolts.

This design gives a high degree of flexibility and allows for considerable radial, angular and axial misalignment of the shafts. It provides ample protection to both driving and driven machinery because of the adequate damping effect on vibration and the absorption of shocks.

It will be readily appreciated that easy and quick replacement of the rubber cushions can be made when necessary. Retaining screws have only to be slackened to allow the rubbers to be removed and replaced without having to dismantle the shafts or equipment in any way.

Three sizes of rubber cushion cover the whole range of couplings available from fractional up to 70 h.p. Each size of cushion caters for six sizes of couplings which vary from each other by the number of cushions employed.



Three-cushion flexible coupling. The U-shaped cushions are of nylon-reinforced rubber

Jet Noise

By F. B. GREATREX*

No. II—(*Continued from page 25, July 1st*)

In this paper, presented last week before the Anglo-American Conference of the Aeronautical Society and the Institute of Aviation Scientists at Los Angeles, detailed measurements made of the noise field round various jet engines, particularly the "Avon," are described. Of the various noise reduction devices tested, the "toothed" nozzle has been discarded owing to its adverse effect on engine performance. A series of "corrugated" nozzles having no effect on engine performance has been found to give worthwhile noise reductions. The three main conditions under which jet noise affects the community are examined—during ground-running, shown to be effectively silenced by a ground muffler; from aircraft passing overhead during take-off and approach, measured to be 9 db worse on take-off with standard jet engines than with propeller engines; and inside aircraft.

Total Acoustic Power Output

By extrapolating the total noise measurements to zero at 0 deg. and 180 deg. to the jet axis the total acoustic power outputs of the jet from these three engines at various jet velocities can be calculated.

According to Lighthill's theory this acoustic power output should be proportional to $\rho^2 A V^n$ where

ρ=jet density.
A=jet area.
V=jet velocity.
n=about 10 for jets of this range of velocity.

The measured figures have therefore been

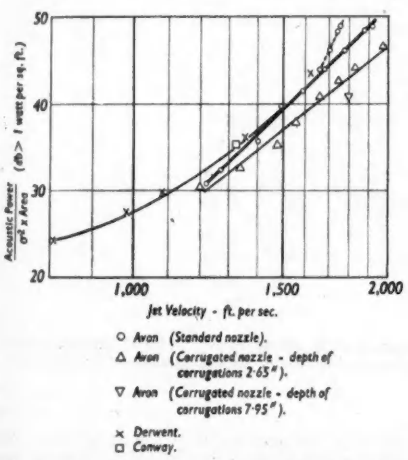


Fig. 8—Total acoustic power output of various engines with standard and corrugated nozzles

divided by $\sigma^2 \times A$ (where σ is the relative density) and plotted against jet velocity in Fig. 8 as acoustic power output per square foot of jet area. For the "Avon" figures where some of the higher points were at jet pressure ratios above the critical (i.e. the jet was choked) the results have been plotted against both the choking velocities (i.e. Mach. Number of 1 in the nozzle) and the fully-expanded supersonic velocities (i.e. assuming adiabatic expansion down to atmospheric pressure). The latter is the more logical procedure, since the jet does in fact expand down to atmosphere in a series of expansion waves, and a single straight line can then be drawn through all the subsonic and supersonic points.

All the points for the three engines lie on this line with the exception of the lower r.p.m. points on the "Derwent."

Inspection of the noise spectrum at these low r.p.m.'s shows a relative increase in the high frequency noise corresponding to compressor noise, which evidently predominates under these conditions. Where the jet noise predominates, however, the total acoustic power output per square foot apparently varies as the jet velocity to the power of 9, in good enough agreement with the Lighthill theory. It is interesting to note that, putting in the appropriate figures for jet velocity, density and diameter, the total acoustic power output of an engine of 10,000 lb thrust is about 100 h.p., the addition of afterburning to such an engine (as calculated by extrapolating the same line of noise versus velocity) would raise this to about 1000 h.p. of noise!

Noise Reduction Devices

Obviously there is a strong incentive to find a means of reducing this noise. Many different devices have been tested on a model scale, and some have been tried out full scale.

Toothed Nozzle.—The first one that showed any promise in a full scale test was the toothed nozzle originally tested on a model scale by Lilley at Cranfield. On a "Derwent" engine (see reference 5) it was found to alter the noise distribution pattern such that the relatively low frequency noise at small angles to the jet axis was reduced, but the high frequency noise at large angles was increased. This characteristic is valuable in that the high frequencies are far more easily attenuated, and was worth examining more thoroughly. The measurements have therefore been repeated on the "Avon" engine on the open-air test bed, in very much greater detail, with substantially the same results as described above. Calculations of the total acoustic power output showed that there was an increase of 4½ db compared with the conical nozzle at 1300ft per second jet velocity, and ½ db at 1800ft per second. These results agree reasonable well with recent measurements made by the N.A.C.A. (7) at Cleveland.

Unfortunately on the "Avon" engine the "teeth" had a serious effect on engine performance, reducing the thrust and increasing the specific consumption by 2 per cent (on the "Derwent" engine the effect was negligible). These performance losses are of course higher than can be tolerated, and the toothed nozzle has been abandoned as a noise reduction device.

It is still of interest, however, to discuss the mechanism whereby the "teeth" affected the noise. One obvious characteristic of the jet from the toothed nozzle is its much greater angle of spread; this can be seen very clearly in the photographs of Fig. 9, in which oil has been sprayed into the jet-pipe some distance upstream of the nozzle in order to make the jet visible. (This is a useful technique for a quick examination of the effect of changes in nozzle shape.) This increased angle of spread implies a more rapid mixing of the jet and the air, which is presumably associated with a general reduction in the noise generated. On the other hand the teeth themselves produce a large number of (relatively) small eddies which presumably add sufficiently to the high frequency noise to raise it above the original level. The combination of these two effects would produce the measured results.

Corrugated Nozzle.—This clue of the advantages of rapid mixing led to an attempt to reproduce the same effect by greatly increasing the perimeter of the nozzle, without affecting engine performance. The first of the "corrugated" nozzles shown in Fig. 11 was made for the "Avon" engine, and the first satisfactory result was that a test bed run showed that it had no effect whatever on the engine performance, and it produced a marked reduction in noise, as much as 10 db, but only at the highest frequencies.

It was an obvious step to link this high-frequency effect with the small spacing of the corrugations, and to try the effect of increasing this spacing, reducing the number of corrugations. A whole series of these corrugated nozzles was therefore made and tested with the very striking results shown in the figure. The peak value of the attenuation is slightly reduced with the smaller number of corrugations, but the frequency at which this peak occurs is reduced almost directly in proportion.

Now the highest noise levels from a jet engine are mainly in the neighbourhood of the 300–600 c/s octave band, so that the nozzle with six corrugations, giving a reasonable attenuation over the frequency range from 150–2400 c/s is clearly the most useful out of this range of nozzles. A detailed set of noise measurements was therefore made with this nozzle, with the results shown as contours for each frequency band in Fig. 12, and for total noise in Fig. 13.

Apart from this attenuation of the middle frequencies, the contours for each octave band are very little different from those with a standard conical nozzle; the total noise contours show the angle of maximum radiation to be rather larger, as would be expected since it consists mainly of noise of higher frequency. At no point in the field is the noise significantly increased, so that in this case there is a definite overall reduction in the acoustic power output. In fact, this quantity has been plotted on Fig. 8, and it can be seen that at the top end of the scale the corrugated nozzle produces a reduction of about 4 db in the total acoustic power output.

The next step was to experiment with deeper corrugations. The original series of corrugated nozzles all had a depth of corrugation of 2·65in, extending 1·25in above and 1·4in below the 19·5in diameter of the circular nozzle of the

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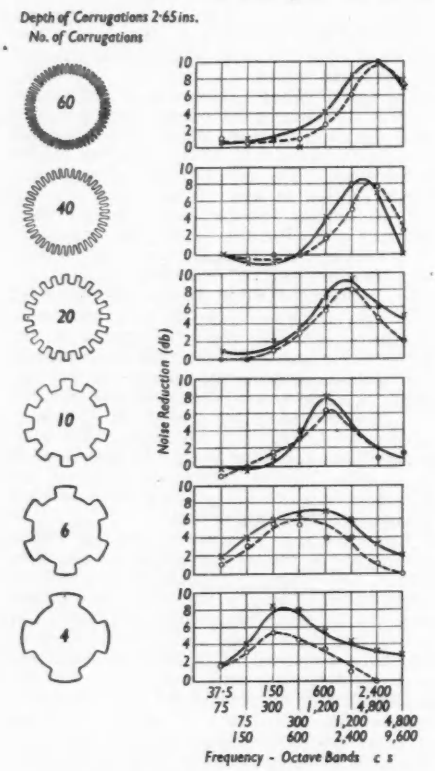
The increased angle of spread when a toothed nozzle is used is revealed by these comparative pictures.

Figs. 9 and 10—Spread of jets from standard and toothed nozzles

same area. A six-corrugation nozzle of twice the depth of corrugation, i.e. 5·3in, was therefore made, and found to give attenuations of 10 db to 12 db, but also a reduction in thrust of nearly 2 per cent. This was due to this nozzle being of the same length as the original one, and consequently the angle of convergence of the inner walls of the corrugations was too great. Another nozzle of twice the length was made and the thrust loss disappeared. In all further tests on corrugated nozzles, therefore, the angle of convergence of the inner walls was limited to 12 deg.

Unfortunately most of this extra attenuation



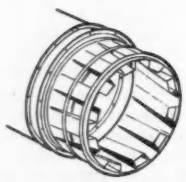


Fig. 11—Noise reductions with corrugated nozzles on "Avon" engine. Effect of varying number of corrugations

was also lost with this lengthened nozzle, but a further increase in depth of corrugation to 7·95in produced peak attenuations of over 12 db, still without any effect on engine performance. The results are shown in Fig. 14 compared with those for the original nozzle with six corrugations. The total acoustic power output has been calculated for the nozzle with the deepest corrugations, and also plotted (a single point only) on Fig. 8; the reduction is about 7 db at the highest jet velocities.

It seemed that the "aspect ratio" of the corrugations of this last nozzle was such that the air flow into the bottom of the corrugations would be seriously restricted, and the next two nozzles of Fig. 14 were therefore tested. These had the same depth of corrugation, but only four and three corrugations respectively. The results show the same sort of reduction in peak attenuation frequency as was found in the original series of nozzles, but the amount of attenuation was slightly reduced However, the amount of attenuation has been found to depend on the depth of corrugation for both the six-corrugation and the four-corrugation nozzle, so the next step is obviously to take the depth to its limit and nozzles of the shapes shown at the bottom of Fig. 15 will be made and tested.

Noise Reduction Mechanism.—Lighthill's theory gives a very satisfactory general account of the mechanism of noise generation by a jet, but in order to understand the selective effect of these corrugated nozzles some further information is needed, particularly on the distribution of noise along the jet. The following very simplified analysis seems to give a crude picture of this distribution which lines up with known facts.

Fig. 15 (*a*) illustrates diagrammatically the spread of a jet from a circular nozzle. The shaded portion represents the core of uniform velocity which persists for about five diameters downstream of the nozzle; the outer lines represent the edge of the jet spreading at an angle of about 15 deg. (total included cone angle). The mixing region in which the noise is generated lies between the edge of the jet and the core, or further downstream between the edge and the centre of the jet.

In Fig. 15 (*b*) the peak velocity in the jet has been plotted against the distance down the jet, and in Fig. 15 (*c*) the area of the mixing region. Now if the assumption is made that the noise generated at any station down the jet is a function of the area of the mixing region and the peak velocity at that station (neglecting the density term, since the mean density is constant over the length of the core and only varies very slowly downstream of it), then the noise energy variation down the jet is shown in Fig. 15 (*d*) (using the eighth power law of Lighthill's original theory). Furthermore, it is reasonable to assume that the frequency associated with the noise at any station is a function of a typical velocity divided by a typical length at that station; Fig. 15 (*e*) therefore shows the variation (of peak velocity per width of mixing region) down the jet.

Substituting the appropriate values of V and D for the "Avon," and putting in an entirely arbitrary constant to give frequency $=\frac{1}{5}\frac{v}{d}$, the curves of Fig. 15 (*d*) and (*e*) have been replotted in Fig. 15 (*f*) as relative noise energy per cycle against frequency, and compared with the measured results obtained over the usual eight-octave bands on the "Avon."

The coincidence of the frequency of the peak of this calculated curve with that of the measured results has no significance, of course, since it has been deliberately chosen to agree reasonably well, but it is of interest to compare the predicted variation of predominant frequency down the jet with Hubbard and Lassiter's measurements on a model jet.[8] In this case, the jet diameter and velocity were 1in and 700ft per second respectively, and the agreement is quite good except in the immediate neighbourhood of the nozzle (as might be expected since the "theory" predicts an infinite frequency at this point). The calculated variation of noise energy with frequency on either side of the peak shown in Fig. 15 (*f*) is also of interest and is really in very fair agreement with the measurements.

According to this very crude picture of the noise generation the noise level increases from the highest frequencies near the nozzle to those frequencies corresponding to the peak noise at the end of the core, solely due to the increase in area of the mixing region, and then falls off at lower frequencies due to the reduction in the peak velocity at the centre of the jet. This picture is no doubt grossly over-simplified, since it uses the final formula of Lighthill's theory and ignores entirely its shear and turbulence derivation, but

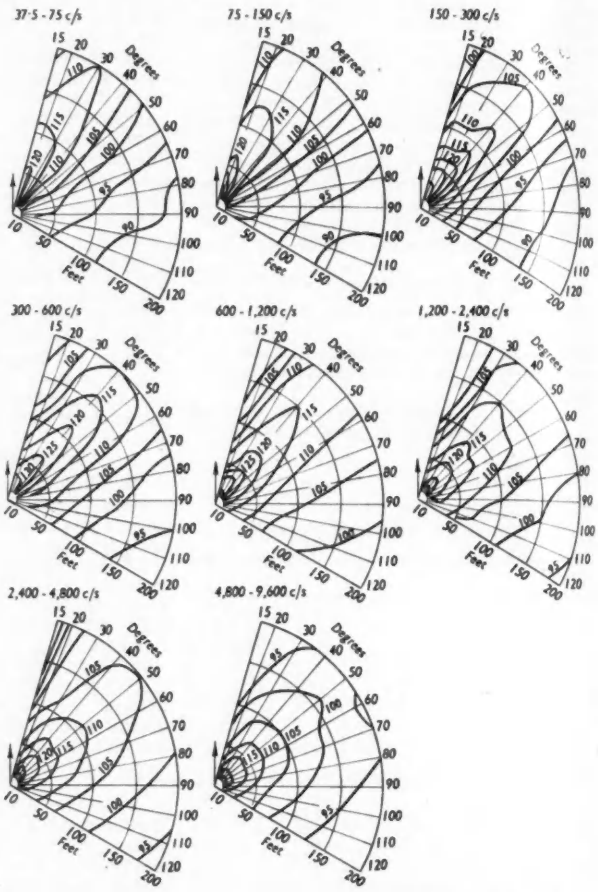


Fig. 12—Noise level contours in eight octave bands. "Avon" engine, 1800ft per second jet velocity. Corrugated nozzle, six corrugations of 2·65in depth

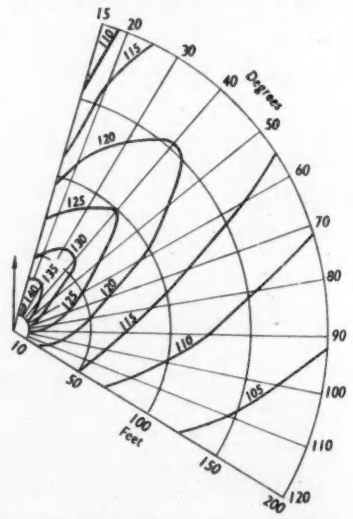


Fig. 13—Total noise contours. "Avon" engine, 1800ft per second jet velocity. Corrugated nozzle, six corrugations of 2·65in depth

it does give some sort of quantitative explanation of the experimentally observed facts. Incidentally it has the merit of not postulating an unexplained increase in the turbulence in the mixing region to a maximum, followed by a decrease. Some measurements recently made by Murray (of the Rolls-Royce combustion department) show that in fact the turbulence is greatest near the nozzle. Fig. 16 shows some results of this work in which

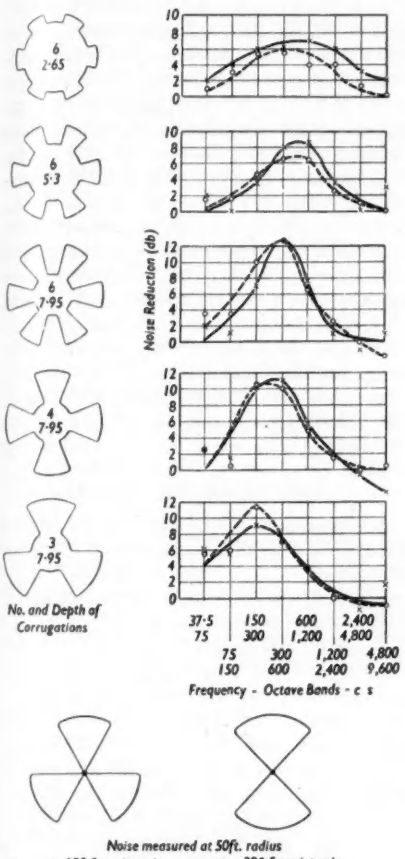

6 2·65
6 5·3
6 7·95
4 7·95
3 7·95
No. and Depth of Corrugations
Noise Reduction (db)
37·5 150 600 2,400
75 300 1,200 4,800
75 300 1,200 4,800
150 600 2,400 9,600
Frequency - Octave Bands - c s
Noise measured at 50ft. radius
15° from jet axis. 30° from jet axis.
Jet velocity 1,800 ft. per second.

Fig. 14—Noise reduction with corrugated nozzles on Avon engine. Effect of varying depth of corrugations

the degree of turbulence was measured by a method derived from one employed by Schubauer.[9]

The results show that the mixing region is roughly defined by the 10 per cent turbulence contour, and that there is a steady fall-off in turbulence level downstream from a point in the neighbourhood of the nozzle. This method gives only the degree of turbulence, and only in one direction, with no correlation with frequency as can be obtained with the hot-wire anemometer method, but it may be of value in this jet noise work—the instrument used is so simple and rugged that it is hoped that it can be developed for use in the jet of a jet engine, where the hot-wire anemometer probably could not be used.

Referring back to Fig. 15, does this picture of the noise distribution give any clue to the behaviour of the corrugated nozzles ? In a very crude manner it does on the following argument. The effect of the corrugated nozzle is to increase considerably the initial mixing, and hence the mean angle of spread of the jet, until the "corrugations" disappear and the jet becomes circular again ; from this point onwards the jet will spread in the same manner as one that was originally circular. Over the first part of this process the noise energy-frequency relationship will not be affected since the distance down the jet does not appear in this relationship, and similarly downstream of this point there will be little change.

At the actual transition point, however, a high rate of mixing has to die down to a lower rate of mixing, and some reduction of the noise generated in this region might be expected.

Some small-scale model tests on the first six - corrugation nozzle illustrate this change in the rate of mixing. The spread of the jet from this nozzle is shown in Fig. 17, compared with that from a conical nozzle of the same area measured on the same test rig (complete traverses of the jet were made at six stations between the nozzle and the end of the core in order to obtain these results). The initial rapid mixing can be seen to last over the first one and a quarter diameters after which the jet spreads in the same manner as that from the conical nozzle, with a shorter core.

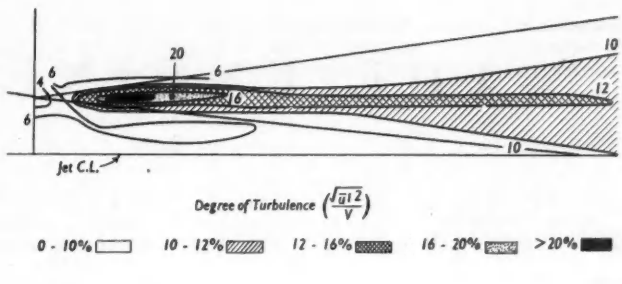
The significant aspects of this result are :

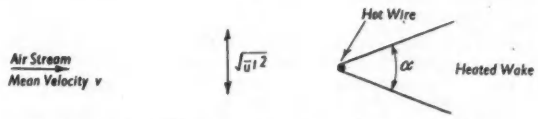
(1) This distance of one and a quarter diameters corresponds quite closely to the distance at which the "spread of the jet" (at the same total angle of 15 deg.) from the sides of the corrugations intersect, at their maximum diameter—i.e. the distance approximately at which the jet might be expected to become nearly circular again.

(2) The width of the mixing region at the one and a quarter diameter point corresponds to a frequency of 530 c/s for the "Avon" at 1800ft per second jet velocity, which is in very fair agreement with the peak of the measured attenuation curve.

On this argument the width of the gap between the corrugations defines the distance downstream at which the rapid mixing ends, and consequently (in conjunction with the rate of mixing) the width of the mixing region at this point, and the depth of the corrugations governs the rate of mixing in this initial region and consequently the change in rate of mixing at the end of it. Hence the almost linear relationship of peak attenuation frequency with number of corrugations, and the increase in attenuation, and slight decrease in peak attenuation frequency, with increase in depth of corrugation.

Unfortunately, this argument gives no clue to the amount of attenuation which might be expected from a given nozzle configuration. Nevertheless, it seems that this very crude picture of the noise generation is worth presenting, as it may be of assistance to practical attacks on the jet noise problem.





V = Jet velocity 88ft per second into still air nozzle diameter 5·3in
$\sqrt{u^2}$ = r.m.s. velocity variation in radial direction.
α = Angle between lines of half maximum temperature rise in wake.
$\sqrt{u^2}$ found from measurement of α and hence $\sqrt{u^2}$ from measurement of $\frac{V}{v}$

Fig. 16—Turbulence measurements in a jet

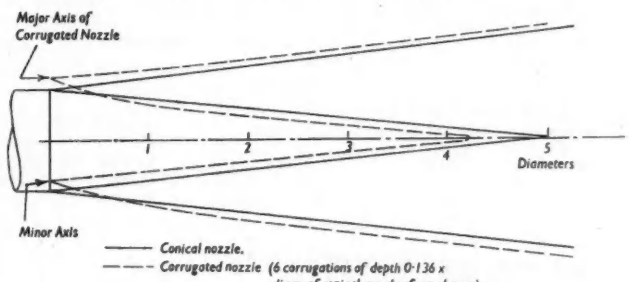

Major Axis of Corrugated Nozzle
Minor Axis
Diameters
Conical nozzle.
Corrugated nozzle (6 corrugations of depth 0·136 x diam. of conical nozzle of equal area)

Fig. 17—Measured spread of cold air jet from corrugated nozzle of 2in diameter

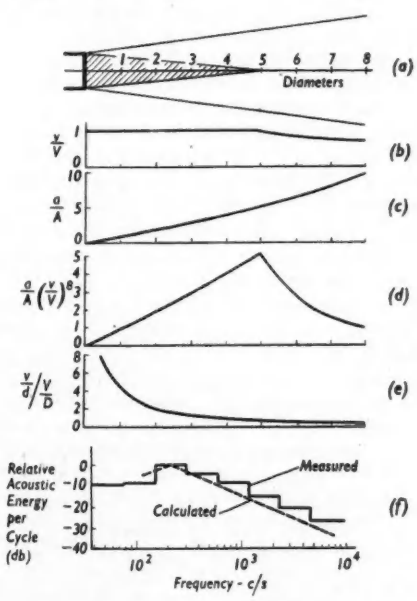


Fig. 15—Variation of noise energy and frequency estimated from known velocity and area variations in a jet

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(To be continued)

MARINE ENGINEERING ESSAY COMPETITIONS.—The Institute of Marine Engineers announces two essay competitions with prizes from the Sir Archibald Denny, J. Stephen, Lord Inverforth, John I. Jacobs, W. Murdoch and D. F. Robertson funds. There is a cash prize of £20 for each competition, one competition being open to all grades of membership of the Institute, and the second being open to students and graduates only. The essays, which must deal with a subject of marine engineering interest, should be from 1500 to 3000 words in length. The closing date for these competitions is October 1st.

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RAILWAY DEVELOPMENT

Since the publication of the British Transport Commission plan for the modernisation of the railways of this country, a great deal of discussion and newspaper comments have been made here. Much of the comment has arisen from a practical appreciation of the difficulties likely to be encountered in the execution of the different parts of the plan—permanent way and locomotive maintenance, staff and labour recruitment, and the capacity of British industry to supply the new equipment required. In broad outline the plan as a whole has not been questioned. On this account it is all the more interesting, and encouraging, to read the outspoken comments of a prominent American transport man, Colonel S. H. Bingham, executive director and general manager of the New York City Transit Authority. In a recent article in our contemporary, *Modern Railroads*, in discussing the problems of American administrations, he emphasises that the United States is not alone in facing those problems. They are international in character, differing from place to place only qualitatively and in detail. He continues: " The British Railways have faced up to this problem and have produced a plan for modernisation and rehabilitation which can well serve as a model for us." Such commendation is praise indeed, but after reviewing appreciatively all details of the B.T.C. plan that are now familiar to us here, and commenting on recent French and Russian developments, he returns to the American problem to hammer home his major point, that the railways of to-day must be prepared to take full advantage of the numerous developments in technology that are proceeding in many branches of engineering. It is in this respect that his article is perhaps of the greatest interest.

Colonel Bingham emphasises the contrast between the conditions of electrical power supply to-day and those existing when many of the major railway electrification schemes of pre-war days were put into commission. Then, in the majority of cases, the railways had to build their own power stations because commercial plants were too small to take the railway load. But to-day, taking the world at large, electric generating stations are no longer confined to the environs of cities, or near to large industrial plants. They are in many cases located where water is available, and they are linked between themselves and with existing plants by a system of high-capacity transmission networks. In this country the network will be reinforced by the output of the projected new stations run by nuclear energy. Colonel Bingham considers that with the continuing growth of the electrical power industry, the general railway load will become increasingly attractive to the industry as a base load, rather than a special load as it is in the majority of instances to-day. The more favourable rates that may develop from this situation, added to the lower capital cost of lineside equipment when taking power directly on the contact line at commercial frequency, may well hasten the conversion of many routes direct from steam to electricity, without the interim period of diesel-electric haulage that is envisaged, for example, in the British Transport Commission plan. With the possibility of using rectifier locomotives further electrification schemes are now being considered by the Pennsylvania Railroad.

Colonel Bingham, from his wide experience, has some interesting things to say about operation, though how far the present trends in American practice could be applied to this country is difficult to see. In the United States it seems that the continuing use of electric and diesel-electric locomotives is enabling the railways to run fewer, but heavier and faster trains. These trains in themselves are markedly increasing the cost of track maintenance and repair, but the reduced density of traffic has led to the remarkable recent decision of the New York Central to abolish all its four-track sections, and revert to double line. Centralised traffic control, with reversible road working, will replace the present signalling arrangements. When it is considered that the New York Central on its " water-level " route operates a very heavy traffic, this is certainly a very bold decision, and a striking commentary upon the way in which C.T.C. can keep a fast and heavy service moving to full advantage. It has already been applied with great success on the Laroche-Dijon section of the French main line between Paris and Lyons. In America not only the New York Central main line, but 300 miles of the Erie Division, is to be similarly equipped. Apart from isolated cases, such as the Laroche-Dijon installation, C.T.C. has hitherto been regarded as a means of signalling for sparsely used lengths of single-tracked railway. Generally speaking, density of traffic is the governing factor where C.T.C. is concerned, but these striking projects on heavily used American lines will certainly be studied closely in this country.

SURVIVAL OF THE PADDLE

As the paddle wheel was the first practical mechanical means of ship propulsion, it has always had a special appeal. It is interesting to recall that as long ago as 1682 Prince Rupert's state barge was propelled by paddle wheels, but they naturally were hand operated. The ancient Latin sages affirmed *facile est inventis addere*, and it is not surprising that its truth was proved when steam was recognised as a motive power, and it was harnessed to the paddle wheel. For many years the paddle steamer remained unassailed on the Atlantic, but in the year 1862 the Cunard Line had the last steamer of this class built. Probably " Scotia " was the most famous and popular of all the paddle liners, and she rendered remarkably good service up to 1875. At this time screw propulsion was definitely asserting itself, and opinion as to its merits was divided; indeed, in 1858 I. K. Brunel was not convinced and accordingly provided both forms of propulsion for his celebrated " Great Eastern." For many years the paddle steamer retained its position for cross-channel work, but in 1875 the London and South-Western Railway abandoned the paddle in favour of the screw, to be followed by the Great Eastern Railway, which also had to maintain relatively long sea passages. The Isle of Man's " Mona's Queen," the last cross-channel paddle steamer, was sold for breaking up in 1929. By this time the prophets were loud in their assertion that the paddle was absolutely doomed. Yet even since the last war modern and well-equipped passenger paddle steamers have been built for service on the Clyde, Bristol Channel and Loch Lomond, the vessel for the last named being put in service as recently as 1953. It is interesting to note that a paddle steamer is operating the day trips to the Continent from South Coast resorts. The high-speed internal combustion engine again seemed seriously to threaten the paddle, but in 1935 the London and North-Eastern Railway had built a vessel whose paddle wheels were

driven by a slow-speed electric motor for which the electricity was supplied by a diesel-electric generator. A year previous to that diesel-electric paddle vessels were put on the Queensferry service across the Forth. The truth of the Latin saying that it is easy to add to things already invented is exemplified by the many steps taken to retain the advantages of paddle propulsion while, at the same time, making use of the most efficient power units. After experimenting with Voith-Schneider fin propulsion on the service between Lymington and Yarmouth with a view to eliminating the paddle, the latest vessel is diesel-electric with chain drive to paddle wheels, which can be operated separately for berthing, and so on.

It would appear that a new lease of life is about to be given to this kind of propulsion, for the Admiralty has decided to have built seven diesel-electric paddle tugs. This decision is of particular interest in that the Admiralty has obtained considerable experience with both paddle and screw tugs, as a result of which the conclusion has been reached that paddle tugs are the more suitable for moving aircraft carriers and other large warships through dock entrances and in the confined waters of dockyard basins. At present it is understood that the Admiralty has ten paddle tugs still in use, and when it is mentioned that the youngest is thirty-nine years old, while the oldest is fifty-six, and the average age of this paddle fleet is 46·3 years, it will be realised that their usefulness has been long proved in a practical way. We are informed that to enable them to operate under the overhanging sides of aircraft carriers, the new tugs are being provided with hinged masts, squat funnels, and raked back stems. The paddles will be feathering, and each of them will have independent drive, but there will be a coupling on the paddle shafts to enable both to be coupled together as required. To enable the tugs to operate as fire-fighting craft a monitor is being fitted on the forecastle deck, which is supplied by a 150-ton per hour pump located in the motor room. Arrangements are being made to have the machinery interchangeable and readily accessible, so that with a suitable provision of spares a defective part can easily be removed for repair and be replaced by a similar unit. Paxman diesel generators provide the power for the motors, the latter being connected to the paddle shafts by chain gearing, which has a reduction ratio of 8 : 1. Both the main generators and the auxiliaries are to be identical with the engines fitted in screw tugs and other Admiralty craft. Each tug will have accommodation for twenty-one people. Orders have already been placed for four vessels, and the two being built at Scotstoun will shortly be laid down, their names being " Director " and " Dexterous."

With these vessels in view we can hardly conclude that the day of the paddle vessel is nearing its end, indeed it is possible that when these new tugs prove their capabilities other tug owners may take note and be encouraged to appreciate the value of vessels with independent paddle wheels, and even go so far as to build some for their own work. For shallow rivers the stern wheeler continues to find favour and is likely to remain with us, while for crowded waterways the quick braking of the paddle is a very definite asset, and on winding rivers much can be claimed for the use of independent paddles. Bearing everything in mind, we do not propose to assume a prophetic role, but rather leave the matter *sub judice* for the future to reveal whether the paddle is to remain indefinitely a recognised form of propulsion. Sentimentally it would be a sad day if a paddler no longer was there. Undoubtedly the performance of these new tugs will be watched with keen interest, and we feel that it is probable that the confidence of the Admiralty in building so many will prove to be justified.

Obituary

NORMAN ALFRED YARROW

SHIPBUILDERS and especially those engaged in the industry in Canada will have learnt with regret of the death of Norman Alfred Yarrow, which occurred suddenly in London while on his way to Spain for a holiday. Norman Yarrow, who was born at Blackheath on July 10, 1891, was the second son of the late Sir Alfred Yarrow, Bt., and brother of Sir Harold Yarrow, Bt., the chairman and managing director of Yarrow and Co., Ltd., and was educated at the University College School, London. His early engineering training was obtained with D. Napier and Son, and then for two years he gained further experience at the works of W. H. Allen, Sons and Co., Ltd., at Bedford. At the end of 1913 the British Columbia Marine Railway Company's holdings at Esquimalt were taken over by Yarrow and Co., Ltd., and in the following year Norman Yarrow went to Canada to take charge of the yard and continued to direct the shipbuilding and repair operations until the business was sold a few years ago. The yard, situated on the southern shore of Esquimalt Harbour, developed into an important shipbuilding, marine engineering and ship repair centre under the control and direction of Norman Yarrow, helped to a considerable extent by the building of a large dry dock at nearby Langs Cove by the Federal Government. After the sale of the business to other interests Norman Yarrow, who had spent practically the whole of his working life in Canada, continued to make his home in Vancouver and was an infrequent visitor to this country.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

MODIFICATIONS OF THE NUTTING LAW APPLIED TO CREEP BEHAVIOUR UNDER VARIABLE STRESS

SIR,—In your recent report on the discussion of papers presented at the Annual Meeting of the Iron and Steel Institute, some of my comments on the paper by Graham and Walles were included. But owing to the condensed form of your report my main points were not made clear.

In recent years, constant stress creep test results have often been correlated by means of the simple Nutting power law connecting stress, strain and time. However, this law fails if any variation of stress takes place during a creep test, or during service life. In choosing a modification of the Nutting law which is more flexible in its application, it is necessary to choose a law governing instantaneous strain rate. Some simple laws may be proposed which will reduce to the Nutting law for simple stress histories, such as constant stress, constant strain rate, or constant rate of application of stress. Some equations of this type are as follows:

$$\dot{\varepsilon}=\kappa_1\sigma^{\alpha_1}\varepsilon^{\beta_1} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\dot{\varepsilon}=\kappa_2\sigma^{\alpha_2}t^{\gamma_1} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\dot{\varepsilon}=\kappa_3\sigma^{\alpha_3}\varepsilon^{\beta_3}t^{\gamma_3} \quad . \quad . \quad . \quad . \quad (3)$$

(σ=stress ; ε=strain ; t=time ; $\kappa, \alpha, \beta, \gamma$ constants)

All equations of this type seem to have advantages over the Nutting law, since they are " history sensitive " equations, but the choice is wide. Equation 1 is a form used by R. W. Bailey, and equation 2 when modified to embrace the Boltzmann memory principle has been adopted by Graham and Walles. It seems that little data is available to support the adoption of any particular law to deal with stress history effects. It is interesting that the properties of equations of the above type have rarely been examined in detail, and it is my contention that where one particular equation has been used the choice has been largely arbitrary.

B. B. OVERY

Queen Mary College,
London, E.1.

POLYTROPIC EFFICIENCY

SIR,—In connection with the letter by Mr. E. A. Bruges on polytropic efficiency (issue dated April 22nd), it might be of interest to note that the flow work done W, including K.E. generated, during various types of expansion of a gas from p_1v_1 to p_2, letting $r=\frac{p_2}{p_1}$, is :

(*a*) Isentropic, index γ ;

$$W=\frac{\gamma}{\gamma-1}\cdot\frac{p_1v_1}{J}\left\{1-r^{\frac{\gamma-1}{\gamma}}\right\}.$$

(*b*) Adiabatic with friction ; index n ;

$$W=\frac{\gamma}{\gamma-1}\cdot\frac{p_1v_1}{J}\left\{1-r^{\frac{n-1}{n}}\right\}.$$

(*c*) Frictionless polytropic, index n ;

$$W=\frac{n}{n-1}\cdot\frac{p_1v_1}{J}\left\{1-r^{\frac{n-1}{n}}\right\}.$$

(*d*) Polytropic with friction, frictionless index n changed to m,

$$W=\frac{n}{n-1}\cdot\frac{p_1v_1}{J}\left\{1-r^{\frac{n-1}{n}}\right\}$$
$$-\frac{\gamma}{\gamma-1}\cdot\frac{p_1v_1}{J}\left\{r^{\frac{m-1}{m}}-r^{\frac{n-1}{n}}\right\}.$$

There are corresponding expressions when the gas is compressed. The ratios of any two of these give their relative efficiencies.

R. J. WOODROW

South Shields.

VERTICAL BOILER LOCOMOTIVES

SIR,—Due to an unfortunate error, the acknowledgment for the loan of photographs and drawings in a recent series of articles under this heading did not appear under the appropriate illustrations, as stated in the text, and I should be grateful if you would allow me, through these columns, to correct this apparent discourtesy.

Fig. 1 was by courtesy of British Railways, Southern Region ; Fig. 3, by L. Larkin, Putney ; Fig. 4, Editor of *Engineering* ; Fig. 5, Major Taylerson, Reigate ; Fig. 6, A. Shanks and Son, Ltd., Arbroath ; Figs. 7 and 8, Hunslet Engine Company, Ltd., Leeds ; Figs. 9, 20, 21, 31, F. Jones, London ; Fig. 10, J. Hayes, Forest Hill ; Fig. 11, D. Stoyel, Orpington ; Figs. 12, 13 and 14, Yorkshire Engine Company, Ltd.,

Sheffield ; Figs. 15, 16 and 17, W. H. Whitworth, Manchester ; Figs. 19, 33 and 34, G. Alliez, Twickenham ; Fig. 22, Greenwood and Batley, Ltd., Leeds ; Fig. 23, Ransomes and Rapier, Ltd., Ipswich ; Fig. 24, Institution of Locomotive Engineers ; Fig. 26, Institution of Civil Engineers ; Fig. 27, Beyer, Peacock and Co., Ltd., Manchester ; Fig. 28, J. B. Latham, Woking ; Figs. 29 and 30, Sentinel (Shrewsbury), Ltd.; Fig. 32, Richard Duckering, Ltd., Lincoln ; Fig. 35, Fodens, Ltd., Sandbach ; Fig. 36, George Russell and Co., Ltd., Motherwell.

R. ABBOTT

Oxford, June 24th. 1955.

Short Notices

Landolt-Börnstein, Zahlenwerte und Funktionen. Vol. IV, "Technik," Part I. Sixth edition. Springer-Verlag, Reichpietschufer 20, Berlin, W.35. Price DM. 288.—The sixth and completely revised edition of the Landolt-Börnstein Tables is now in course of preparation. It will for the first time include a collection of data from the field of technology and the engineering sciences to be issued in four parts as Vol. IV, "Technology." The first of these parts has now been published, and deals principally with non-metals. The second will deal with metals ; the remaining two, with electric and magnetic properties, light and X-rays, and with thermal properties.

As regards the arrangement of the subject matter, this has been done purely from the point of view of convenience in use. In this way, the present volume has been arranged according to the different groups of materials. These sections are followed by others dealing with the various physical properties, such as friction, viscosity, flow of liquids and gases, flotation and acoustics. In certain cases (e.g. wood and plastics) the electrical and thermal properties have also been listed in order to avoid having to turn to different volumes of the tables for data on these important substances. Great importance has been laid on a simple and clear manner of presentation. Of particular value in this connection will be found the introductory section on definitions and units. Apart from directly measurable quantities, there are many tables listing derived quantities of technical importance. The work is intended not only for the research worker, but for industrial and technical readers generally.

Iron Moulding for Apprentices. By F. D. Roper. London : Ernest Benn, Ltd., Bouverie House, Fleet Street, E.C.4. Price 15s.—This is essentially a practical reference book, designed to enable foundry apprentices to widen the knowledge gained by experience. Opening with a brief history of the craft, its various sections deal in a clear way with the principles of moulding, box parts, venting and ramming, open sand moulds, irregular joints, moulding techniques, loam moulding, cored work, gating methods, fluid pressure, foundry sands, and care of patterns. Like most books of its kind, it appears at times to overstress the obvious, but the detailed way in which the author covers each stage involved in producing good-quality castings will make it a useful addition to the apprentices' bookshelf.

Books Received

Electric Melting and Smelting Practice. By A. G. E. Robiette. London : Charles Griffin and Co., Ltd., 42, Drury Lane, W.C.2. Price 50s.

Symposium on Sinter. Special Report Number 53. Published by the Iron and Steel Institute, 4, Grosvenor Gardens, London, S.W.1. Price 37s. 6d.

Materials of Construction. Sixth Edition. By the late A. P. Mills. London : Chapman and Hall, Ltd., 37, Essex Street, Strand, W.C.2. Price 60s.

Electroplating Engineering Handbook. Edited by A. K. Graham. London : Chapman and Hall, Ltd., 37, Essex Street, Strand, W.C.2. Price 80s.

Electromagnetic Principles of the Dynamo. By E. B. Moullin. London : Oxford University Press, Ltd., Amen House, Warwick Square, E.C.4. Price 50s.

Study of Engineering History

By PROFESSOR AUBREY F. BURSTALL*

In this lecture to the Newcomen Society presented at King's College, Newcastle, on June 7th, the subject is the study of engineering history—how it is being developed in the mechanical and marine engineering department of King's College, Newcastle. It describes what has been and what is being done to try to make this particular study a formal mental discipline that may appropriately be followed by selected engineering students as part of a course leading to a University Degree in Mechanical Engineering.

MUCH of what we are doing in this connection has not been done in a University before—at least not in this country—so we had no precedent to follow. We have, of course, made all the mistakes that beset those who dare to set foot on new ground, but our experiment—for we are still in the experimenting stage and liable to make changes in the hope of getting improvement—is now at the end of its third year, and you may like to hear some of the conclusions that have been reached.

Before this experiment began, the author had for many years been accustomed to organise each year an elementary descriptive course of lectures for freshman students dealing with the history of various aspects of engineering such as motive power, production engineering, and structures. These were essentially popular lantern lectures designed to give the student some idea of the most important engineering achievements of the past ; they were interesting rather than profound, but they served to provide a historical background for the more technical aspects of his engineering studies. They could be described as a course to initiate the young student into the mysteries of the engineering profession. To quote the words of an editorial in *Engineering*[1] "the subject had hardly passed beyond the stage of nursery legend." From time to time these elementary lectures were supplemented by special lectures and addresses requiring a higher level of thought on, for example, "Men and Machines," "The History of Power Transmission," the works of Henry Ford, Leonardo da Vinci, Sir Charles Parsons and others. The preparation of these lectures and the reading that they involved, suggested that there were many inspiring lessons to be learnt from a careful study of the achievements of the engineers of the past. It was appreciated too how cogent were the comments of the late Dr. H. W. Dickinson who, in addressing the students of Renselaer Polytechnic Institute in 1938, remarked "there is great educational value in the study of the history of engineering. It is consecutive, rational and evolutionary in character. One step in advance is seen to lead logically and inevitably to the next."

For many years the writer was dissuaded from taking the plunge and attempting to teach engineering history himself, by views so aptly put in an editorial in *Engineering*, "Few of those who essay to teach it have ever undertaken any historical research—a most exacting pursuit—or are in a position to review critically the texts on which they rely." Dr. Sherwood Taylor has drawn attention to the danger of relying not on the ultimate facts of history and of science, but on the generalisations and conclusions of other men.[2] This implies that only a professional historian is qualified to teach the history of engineering and, accepting this view, the writer endeavoured to secure the appointment of a professional historian as a member of his own department of engineering but without success. The idea was anathema to all the accepted academic traditions of University organisation. The challenge that remained was "Do it yourself if you believe in it ; otherwise drop the idea." The challenge was accepted with some misgivings.

The main considerations which governed the choice of methods for teaching the history of engineering to engineering students were these:

(1) In a three-year undergraduate course, the only period available for the serious study of engineering history was in the third or final year. Credit had to be awarded to the student both for course work done during the year, and for answering written questions in the subject in the final examination.

(2) The primary discipline that the students were required to undergo in this subject was to learn to read critically. They were expected to read much more in this subject than in others of the course and to discriminate in their reading. The measure of their success in this respect was judged by their powers of selecting what was relevant in answering any question, and by their ability to explain the developments of the past in terms of logical sequences of relevant events.

(3) Since only one-sixth of the student's time in his final year could be devoted to this subject, means had to be found for restricting the field of enquiry of individual students so that they might do some one thing thoroughly. At the same time they had to acquire sufficient knowledge of the broad facts of the history of technology to develop that breadth of vision that is said to be characteristic of students of history and is in such marked contrast to the narrower and more self-centred outlook that is often attributed to engineers trained in the conventional manner.

(4) The interest and enthusiasm of the students had to be aroused to such a pitch that they would find themselves irresistibly impelled to discover the answers to the questions they were asked.

(5) Since the students would shortly become practising engineers and were not destined for a life of academic scholarship, it was desired to encourage them to work together, and in a measure to learn from one another. Accordingly the conventional lecture system was practically abandoned and its place taken by tutorial group discussions, some assignments being given to the whole class to work out together for a single joint solution.

With these considerations in mind it was decided that the opportunity to develop a broad outlook would be provided by requiring the class to read two or three general text-books on the history of engineering, and to discuss these together chapter by chapter at weekly tutorial meetings. The three texts chosen at the outset were : "Man the Maker" by Forbes, "Technics and Civilisation" by Mumford, and "Men, Machines and History" by Lilley. The tutorial group discussions were supplemented in a number of ways to broaden the outlook of the students still further : by lectures on the history of mechanical engineering applied to agriculture, on mechanical engineering in Roman times (by Professor Richmond) and by some general lectures concerned with the history of power production, power transmission and mechanical transport. During the Christmas vacation the students spent three whole days at the Science Museum, South Kensington, where by courtesy of the director special lecture demonstrations were given to them by the staff in the galleries on hand and machine tools, prime movers, textile machinery, printing, time measurement and calculating machines. Notes were taken by the students at these lectures and joint reports prepared.

During term time, half-day visits were paid to the local industrial museum, and to old machinery in the locality such as beam engines, water wheels and flour mills. Professor Richmond also conducted the class on an expedition to the Roman wall. Finally, a number of sound films were exhibited to the students showing Cornish engines, early steam boilers and other features of engineering history appropriate to the course.

The principal drawback to these forms of

* University of Durham.

mental excitement is that they appear to produce in the student a kind of mental indigestion. He is apt to be bewildered by such an array of apparently disconnected facts and ideas that are new to him in respect of the past, so that he becomes confused by trying to learn too much, too quickly, and often he gets his dates wrong. Matters are not made easier by the way that suitable texts have been written, for they usually require the reader to switch his interest from one subject to another in reading of successive periods in history, or, as Usher has pointed out recently, the processes of change have been partly concealed by the conventions of the "Great Man" theory of history.[3] Dr. Singer, in the first Dickinson Memorial Lecture delivered before this Society a year ago, voiced the same view: "What an interesting history could be produced on anonymous lines," he said, "especially a history of technology or science. It should mention no names at all, but discuss merely achievements. Such a history could explain how discoveries and inventions are related to and, indeed are a part of, the social scene of each successive age."[4]

Unfortunately, no such history has yet been compiled, though some valuable historical reviews on specialised subjects have been produced by the staff of the Science Museum, whose handbooks provide for students some of the best examples of how historical data relating to engineering events should be assembled to show the evolution of industrial techniques throughout the ages.

Before the course was started it had been intended to use Mumford's book *Technics and Civilization* to provide a general background, since it has been written on these lines and contains some well-reasoned reviews of the influence of mining on modern technology; of the woodman as the primitive engineer; of the influence of warfare upon invention, and a whole host of interesting ideas of a general character. Moreover, the book has an excellent bibliography and lists of inventions in each century. However, it was soon found to be unsuitable for our purpose because it directed the students' attention more towards the sociological implications of the facts of engineering history than towards a study of the engineering aspects of technical achievement. Lilley's book, *Men, Machines and History*, was tried with the same result, though both remain useful for reference and Lilley's analysis of the relative invention rate at different periods of history is well worth consideration.

The book by Forbes entitled *Man the Maker* has been found the most useful for providing general background information, though it has many limitations, so that we have been constantly on the look-out for something more useful to our purpose. While it has the virtue of directing attention to the engineering aspects of technological progress, the manner in which it is written is unfortunate. Successive chapters are devoted to different periods of history from the earliest times up to the present, and each chapter is divided into sections that are concerned with different technologies, e.g. power sources, ships, metallurgy and chemical technology, and the range of subject matter is wider than is appropriate for a course confined to the history of mechanical engineering. For these reasons, the recent reprinting of Usher's book entitled *A History of Mechanical Inventions*, is welcome and this will probably be used for some time as the most suitable text available for providing background information. Apart from the philosophical review in the first five chapters, there is an excellent account of the mechanical equipment of pre-Christian antiquity and a useful summary of the mechanical achievements of Leonardo da Vinci, the rest of the book being concerned with five branches of mechanical engineering history (1) water wheels, windmills and motive power; (2) clocks and watches; (3) printing; (4) textile machinery, and (5) machine tools and quantity production. Usher seems to be fully aware of the dangers of superficiality and muddled thinking when the student is presented with too broad a view, for he writes (page 19), "adequate historical analysis requires attention to be concentrated on particular sequences of events," and he devotes the whole of one of his philosophical introductory chapters to what he calls "the particular system of events," where he concludes (page 42) that "To be significant for historical analysis and description the particular system of events considered should be less extensive than would be suggested by underlying principles of science and philosophy." This conclusion accords with our experience in Newcastle when giving the course under discussion; it was revealed most clearly in the thesis work undertaken by each student to comply with our requirement that the history of some one thing should be studied really thoroughly. The subject of his thesis was given to the student at the beginning of the session so that he had seven months in which to read up the history of his subject. He was then asked to write a dissertation or thesis of not more than 5000 words to be accompanied by diagrams and illustrations. The subjects of the dissertations were:

1952–3, four students: The steam locomotive, the reaction steam turbine, the two-stroke marine oil engine, gas-making plant.

1953–4, eight students: Windmills, water turbines, the printing press, irrigation machinery, strength of materials, stationary land boilers, oil well drilling machinery, piston engines for aircraft.

1954–5, eleven students: The Jacquard loom, mowing machines, the water closet, the weighing machine, centrifugal pumps, mechanical clocks, the baker's oven, nuts and bolts, locks and safes, brick-making machinery, glass bottle making machinery.

Notice that each year the system of events to be considered by the student has been less extensive than the year before, and this is believed to be one of the reasons for the improvement in the quality of the work that has been observed. Next year the same policy will be followed of reducing still further the range of subject matter to be considered in each dissertation.

In marking the dissertations, the examiners try to assess the skill shown by the candidates in selecting and presenting the material. Usually, the writing is in narrative form and papers that are well written and well illustrated are inevitably given some marks for these qualities. However, as Usher has pointed out, the convention that historical writing should be presented in narrative form has obscured the importance of criticism and the use of analytical procedures in history, so the students are encouraged to make use of comparisons, lists, tables and graphs wherever they may be appropriate. The candidates may be given an oral examination on the thesis, primarily to ascertain how much original work has been put into it by the student himself.

Skill in the selection of the material is judged by its relevance, and the presentation by the logical sequences, illustrations and ideas that are used in their interpretation. One of the more popular devices that has been used is to append at the end of the paper a chronological sequence of events with dates, names of inventors and related incidents so as to portray the main developments in the field under review in a tabular form. The compilation of at least one of these tables for a broader field of events is one of the joint tasks undertaken by the whole class working together and using as models the excellent charts on events in the development of prime movers, railway transport and pumps that have been published by the South Kensington Science Museum. Similar charts have been prepared by the students to record the principal events in the history of textile machinery, firearms and guns, and hand and machine tools. In many respects these charts are amateurish and incomplete, but the experience of compiling them as a creative activity, jointly undertaken, promotes useful discussion and interest among the students and helps them to acquire rapidly a sense of the different periods of history.

Students are expected in their dissertations to provide some sketches made by themselves, though illustrations from other sources are not debarred. The test of excellence is whether they are relevant and necessary to the argument and introduced at the right place. Accordingly illustrations are best in the text and not at the end of the document. Great importance is attached to the list of references, numbered for acknowledgment throughout the text, so that it is perfectly clear when material has been used. The commonest faults in dissertations are that they contain too much descriptive matter and not enough critical discussion, and that too many quotations from different sources, strung one after the other, make the style disconnected and the argument difficult to follow, if not actually misleading, as, for example, when successive authorities quoted use different words for the same thing. Lists of advantages and disadvantages also impair the style, particularly if they appear too often.

In tracing the evolution of mechanical processes, machines, or machine elements, it is important for students to draw comparisons from as many points of view as possible. Thus when discussing weighing machines, for example, it is of interest to record, apart from the different mechanisms that have been used, what changes have taken place in the accuracy and sensitivity of these machines, how the numbers of machines produced have varied, how their cost has changed over the years; how the specifications and tests have altered, whether the raw materials of manufacture and the methods of production are the same and to what extent the machines are now automatic. In many cases it is difficult to obtain information of this kind, and when it can be found it usually does not go very far back. Nevertheless, whenever it is forthcoming, as sometimes by writing to firms that have been long established in the same business, it adds greatly to the interest and value of the work and gives the student some insight into the variety of factors that have to be considered in commercial engineering.

Source material for these dissertations can usually be found by searching in the local libraries among such references as *The Transactions of the Newcomen Society* and historical papers to scientific societies and journals; *The Encyclopædia Brittanica* and *Chambers's Encyclopædia*; *Histories of Science and Technology*, e.g. that edited by Singer; *Handbooks and Charts of the Science Museum*; histories of particular sciences, trades or institutions; stories of the development of particular machines or firms; collected papers and biographies of scientists and engineers, such as those by Dickinson, Smiles and others.

The course work in this subject is performed, not in the laboratory, but in the library, and to get engineering students used to working in a library is an achievement in itself. THE ENGINEER once admitted in its editorial that "engineers, taken in the lump, are not booky people, perhaps, like Aloysius Horn, they don't hold with reading, if it can be helped."[5] So much the worse for them! It can hardly be denied that the cultural and intellectual standards of the engineering profession have suffered from the aversion to serious reading that is so common among professional engineers. It is least excusable in the graduate from the university, for the hallmark of his education should be his interest and ability in reading. Students of this course are encouraged to borrow reference books from local libraries, and to do their reading wherever they wish. However, it is most desirable that there should be some focal point in the department of mechanical engineering where they can work together on joint work and have easy access to books that are in frequent use. Accordingly, when the Stephenson Building was planned we made provision for a departmental library or reading room which is supervised by a competent librarian and already contains a useful collection of books on engineering history as well as other engineering textbooks, catalogues and reprints.

Up to the present the practical work of the course has been confined to visits to the museums at South Kensington and Newcastle, visits to inspect a few examples of old machinery in the locality and a visit to the Roman Wall. The visits to the museums, the laboratory work of the course, so to say, have been in some ways the least satisfactory. One reason is that most of the exhibits were not working. On the rare occasions when machinery has been operated for them, e.g. an old loom in the South Kensington Museum, the interest of the students was fired immediately and they besieged the demonstrator with questions. Another handicap about

museum pieces is that they are not supposed to be touched, much less handled or taken to pieces. Naturally a group of engineering students have more understanding and enthusiasm about old machinery if they can take it apart. We saw this recently when a group visiting a derelict flour mill, driven by a water wheel, took most of the mill to pieces and reassembled it in one afternoon, getting incredibly dirty in the process. But how they enjoyed it and how much better was the report and sketches they produced than anything done at the museum ! Another drawback of museum visits is that one sees too much, too quickly. It is wellnigh impossible to concentrate one's attention on a "particular system of events" for long enough to draw satisfactory conclusions about their causes and effects. Invariably someone in the party is distracted by the intriguing aspect of a neighbouring exhibit and then the train of thought is lost. How much more fortunate are those who dig, for their whole attention is concentrated upon what they find, until it is finally placed in a museum !

At the same time visits to museums are essential for providing a background of reality for the students' reading. Here is proof in actual hardware that the writers of the books have been telling the truth. Students are unanimous in their appreciation of visits to museums and especially of the demonstrations that have been provided for them in the galleries of the South Kensington Museum. Nevertheless it seems to me that much more might be learned from museum pieces, particularly those in our local museum. The first suggestion is to require the students to visit the museum often enough completely to satisfy their curiosity, and after that they should be able to concentrate their attention upon particular items, apart from the distractions occasioned by other members of the public. What would be far better if it were practicable, would be to borrow particular specimens for a period for detailed study, handling, and even dismantling and reassembly, and, where practical, students should be allowed to operate the exhibits. When this last cannot be done, it is suggested that it might be well worth while for a group of students to be responsible for the manufacture of a replica of an old machine in our own workshops, the students measuring up the original, making drawings and calculations, assisting in the assembly, and setting up the machine for test and operating it. Projects of a similar kind, though not associated with engineering history, are undertaken individually by our honours students in their final year with very great success. The experience of doing something new for oneself, even when it is done under supervision, is of the utmost value in developing the assurance and self-reliance of the individual. Where visits can be made to old machinery that is still at work in the locality it should not be sufficient for the students to stand and stare at it, even though that is all they are expected to do by those who have the machinery in their charge. Dimensions should be taken—unless drawings are available—sketches prepared and estimates made of power produced, or consumed, of friction losses and other relevant data, so that the performance of the machine can be compared in the report with that of more modern machinery. Where this can be done it is usually of much more value and interest than studying the same machine in a museum.

The visits to the Roman Wall and the Housesteads Museum, conducted by my colleague Professor I. A. Richmond, have been a great success and have contributed something to the course that could have been got in no other way. The modern student is apt to think that mechanical engineering began with James Watt, or perhaps with Leonardo da Vinci, and it is a salutary lesson to see the traces left by the Romans of their engineering achievements made nearly 2000 years ago. These can be seen in samples of wood joined by nails, dowel pins and metal brackets, in the methods of jointing pipes and lifting large stones, the evidence that flour was ground by water wheels, the hand tools, locks and keys, ornaments and household utensils. All bear witness that many of the engineering arts were well established and understood in Roman times. The astonishment and incredulity of some students when the implications of these relics dawn upon them reminds me of a personal experience at the University of Melbourne some years ago. A local contractor had been called in to make some building alterations in the engineering department and he borrowed from our store a hand drill for drilling some very fine holes. It was explained to him that it was a drill invented by Archimedes. He had not seen one before and was much intrigued by it. When he returned it some days later he remarked "Clever chap, Archimedes. Does he still work here ?"

Both in his lectures and in the field at Housesteads Professor Richmond has supplied, with the touch of the professional historian, a glimpse of how life was lived by the people in this country at one period of history. Notice that this is concerned only with one particular series of events—those that occurred during the Roman occupation of Britain. The engineering practices of those times also serve as a basis from which later progress can be measured.

Having now described the methods we are following in our studies of the history of engineering, I would invite your comments and suggestions. Have we missed a better approach to the subject ? Are we trying to do too much ? It would be particularly valuable to hear from members of the Society which systems of events they consider are most worthy of study for this particular purpose, and what might be the most appropriate sequence ? Should one begin by considering the five simple machines of antiquity —the lever, the pulley, the wedge, the screw, and the wheel and axle—and trace the improvements that have been made to them and the uses to which they have been put ? To do so involves the study of a larger system of events than the beginner can easily comprehend. The biographical method of studying the achievements of particular individuals got over this difficulty and is probably the simplest, but it leads ultimately to the "Great Man" theory of history which hides the essential truth that "every event has its past."

It seems to be necessary to explain in more precise detail what is meant by saying in the words of Dr. Dickinson "the history of engineering is consecutive, rational and evolutionary in character, that one step in advance is seen to lead logically and inevitably to the next." If we take this as our charter then we must be prepared to quote examples of how it applies. One that comes readily to the minds of most mechanical engineers is the steam-operated water pump. Its evolution can be traced according to the "Great Man" theory, through the engines of Worcester, Savery, Newcomen and Watt. This sequence of events has the merit that the events themselves have been fairly well recorded and it is easy to explain why each improvement displaced its forerunner. On the other hand, the steam engine is a relatively complicated machine and the more closely it is studied the more the reader tends to become absorbed in side issues that may seem to obscure the main trend of its evolution. For this reason it may be better to start with something simpler, for example, flour milling machinery, which has evolved from the saddle stone to the quern, from the quern to the flat stone mill, and recently to the modern roller mill. What lessons can we learn from this ? Is it quite clear that each step in advance leads logically and inevitably to the next ? If not, how can we make it so ? The same sort of perplexity is apt to arise in the student's mind with other examples.

We have concluded that some systems of events are too wide and comprehensive for consideration in this way, typical examples being marine engineering, railway transport, automobile engineering, mechanical power transmission, and even motive power. Furthermore, it might be more useful to concentrate our studies into smaller fields and perhaps to specialise on those that have been developed in our local industries, such as the steam locomotive, the steam turbine, guns and glass making.

Some degree of specialisation is probably inevitable if the subject is to be developed to the standard appropriate to a university department, and it is reasonable to expect that more interest and encouragement will be given to it if its main preoccupation is with the engineering history of the region. Similarly, we should expect that when the proposed museum of science and technology has been established in the Manchester area one of its main concerns will be to record the historical development of textile machinery. It has been said very recently that a group of people at the University of Manchester are concerned that the history of science should take a more important place in university education ; some of us here have been equally concerned for a number of years and you have heard how a start has been made to meet this need by providing a course in engineering history for mechanical engineers during the last three years.

In conclusion I should like to add that in my own view the greatest value of the study of engineering history is not to be found in observing its logical sequences, but in something intangible that is hard to express. To study and appreciate the achievements of the past is constantly to receive enlightenment without frustration, and to feel awe and wonder from time to time as one does is to share with one's students a refreshment of the human spirit.

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Paint Development Laboratory

A NEW wing has been recently added to the development department's laboratories of the paints division of Imperial Chemical Industries, Ltd., at Slough. This development department's function is to apply research discoveries to the improvement of industrial and decorative paint products and processes, and it has laboratories at the two main manufacturing centres of the paints division at Slough and at Stowmarket. In addition, it operates at Stowmarket a large exposure field in which paints are exposed to the weather to assess their performance.

The development department has a staff of over 150, divided into teams of from six to ten members under the direction of a senior graduate, and each of these teams deals with paints devised for a particular industry or group of industries. Its main source of inspiration is its associated research department, which is constantly carrying out work on new polymers, resins, pigments and solvents. The research department also studies the chemical and physical problems arising in either the manufacture or use of paint, and provides a constant flow of new information to the development department.

The new wing of the laboratory at Slough will double the existing accommodation for the development department, and in it the staff will be housed on two floors. The layout is designed to give a considerable degree of flexibility in internal arrangements, and for this reason internal columns have been eliminated, extensive use is made of removable partitioning, and services such as cold water, electricity and compressed air are arranged accordingly.

In addition to up-to-date laboratory scale paint-making machinery, paint-testing equipment and photographic laboratories, the new block has two testing rooms in which the atmosphere is automatically controlled to within narrow limits. These testing rooms make it possible to study the behaviour of paints under a variety of climatic conditions. In one room, the atmosphere can be controlled at any temperature in the range 0 deg. to 40 deg. Cent., and relative humidity 50 to 95 per cent at any temperature in the range. In the second room there is no humidity control, and the temperature may be controlled between outside ambient and 40 deg. Cent.

FACTORY EQUIPMENT EXHIBITION, 1956.—The fourth Factory Equipment Exhibition will be held at Earls Court, London, from April 9 to 14, 1956. For this exhibition the whole of the ground floor at Earls Court has been reserved, and exhibits may include any materials or products used in the construction, furnishing, maintenance or operation of a factory, works, warehouse or other industrial establishment, or which contribute to the safety or welfare of employees.

British Instrument Industries Exhibition

No. II—(*Continued from page 22, July 1st*)

THE British Instrument Industries Exhibition, which was opened at Earls Court, London, on June 28th, ends tomorrow, July 9th. Brief descriptions of some of the exhibits are given below.

The Solartron Electronics Group, Ltd.

Phase measuring equipment for testing servo-mechanisms is being exhibited by The Solartron Electronics Group, Ltd., Thames Ditton, Surrey. This equipment is known as a transfer function analyser. It consists of a low-frequency decade oscillator and a low-frequency phase-sensitive voltmeter. As shown diagrammatically in Fig. 3, the oscillator provides a four-phase output of constant amplitude over the frequency of 0·01 c/s to 11·1 kc/s. All four phases are directly connected to the voltmeter to give a reference base and a second oscillator output is applied to the test network under the control of a calibrated attenuator, both balanced and

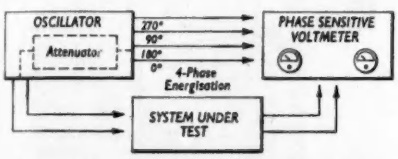


Fig. 3—Schematic diagram of transfer function analyser for testing servo systems. It consists of a low-frequency decade oscillator and phase-sensitive voltmeter—Solartron

unbalanced outputs being obtainable. The output from the test network, whether balanced or unbalanced, is applied to the signal input of the phase-sensitive voltmeter, where it is compared with the reference signal. This comparison takes the form of indications on two 6in thermocouple wattmeters, showing the in-phase and quadrature components of the input signal that is being examined ; the meter readings are in Cartesian form to enable a Nyquist diagram to be plotted simply by transference of the combined reading. Because the thermocouple meters operate in accordance with a product law, their indications are independent of any harmonic content in the input signal channel.

To operate the equipment the primary frequency within the test range is set up on the oscillator decade controls and the input attenuator on the phase-sensitive voltmeter is then adjusted to give convenient meter readings. These readings, in combination, give the first plotting point on the Nyquist polar diagram ; subsequent points on the diagram are found by a simple adjustment of the oscillator frequency.

Any d.c. component up to 600V levels which may be present in the system are blocked from the input to the phase-sensitive voltmeter. The l.f. phase-sensitive voltmeter is stated to give an indication accurate to ±3 per cent, which is equivalent to an angular error of less than 2 deg.

The l.f. decade oscillator is amplitude stabilised to within ±3 per cent over the whole of its frequency range, down to 0·01 c/s. Higher accuracy can be obtained by the use of a manual control in conjunction with a special monitor metering arrangement. The d.c. component in the output of the l.f. oscillator is stated to be less than 1·5 per cent of the peak-to-peak a.c. voltage for all phases. To maintain low d.c. output content at low output levels the oscillator operates at a constant level of 10V r.m.s. per phase and is followed by a voltage dividing system operative on the 0 deg. and 180 deg. output.

This voltage dividing system feeds the following voltages per phase into a 1000 ohm terminating resistance : 10V to 5V in 0·5V steps ; 5V to 2V in 0·25V steps; 2V to 1V in 0·1V steps. Further multipliers of ×0·1 and ×0·01 give the system a total of 99 steps covering 10V to 10mV unbalanced or 20V to 20mV balanced. Dividers are not provided for the 90 deg. and 270 deg. reference outputs, which are available on a 10,000 ohm impedance. The angular accuracy of the quadrature phases is stated to be within ±1 deg. of nominal up to 1 kc/s, and the amplitudes of the 90 deg., 180 deg. and 270 deg. phases to be within 2 per cent of the amplitude of the 0 deg. phase. The amplitude stability of the instrument is specified as ±5 per cent over the whole operating range.

The analyser is suitable for single phase 200V–250V supply at 50 c/s, the consumption being 240W at 230V. As can be seen from Fig. 4, the analyser equipment is in two parts : the oscillator, on the left, measures 22in by 12½in by 13in high and the phase-sensitive voltmeter, on the right, has similar overall dimensions.

This transfer function analyser is useful for test measurements on high-speed servo-mechanisms, for example, in aircraft and guided missile engineering. Closed loop or open loop tests can be made on electrical, electro-hydraulic, or mechanical servo links by using transducers. Sine-wave or square-wave drive is available for step-function response testing.

Other interesting exhibits on this stand include a check weigher for automatically weighing up to 120 items per minute and a motor for driving grinders at speeds up to 100,000 r.p.m.

Metropolitan-Vickers Electrical Company, Ltd.

A vapour-phase chromatograph for analysing and separating gases and volatile liquids is being shown by Metropolitan-Vickers Electrical Company Ltd., Trafford Park, Manchester, 17. In this instrument the sample to be analysed is injected into the top of a column which contains an inert packing such as Kieselguhr, impregnated with a high boiling point solvent. Nitrogen is passed continuously through the column, carrying the sample along with it as a vapour. The various components of the sample mixture pass through the column at different rates ; the time taken to emerge is a characteristic of each component for a particular set of operating conditions. Vapour pressure and solubility in the stationary liquid phase (i.e. high boiling point solvent), affect the time of emergence of components so that the component which is least soluble and of highest vapour pressure emerges first. Good separations can be obtained with many different kinds of compound, such as hydrocarbons, alcohols, aldehydes and ketones.

The relative concentration of a component in the nitrogen stream is indicated by a thermal conductivity cell in the outlet line and a record is obtained by a pen recording instrument. This record is in the form of a series of peaks of conductivity plotted as a function of time. To carry out quantitative analysis, it is necessary to calibrate the instrument with the individual components or, for greater accuracy, with a synthetic blend. Qualitative analysis is assisted by the fact that, for a particular series of organic compounds, there is usually a simple relationship between the time of emergence and the chain length.

Equipment for crystallographic work can be seen on the same stand where there is a Newton Victor "Raymax 60" X-ray diffraction set, designed on the "unit" principle of construction. With this equipment basic diffraction facilities may be extended at will for more complex crystallographic techniques, full provision being made for the installation of additional components.

The equipment consists of X-ray tube and pumping plant, control unit, and high-voltage transformer rated at 60kVp at 20mA. The X-ray tube is demountable and continuously evacuated, providing an extremely fine focus. Target tips are available from a comprehensive range of materials, and are quickly and easily exchanged.

Another exhibit is a Newton Victor "Victrometer" X-ray dosemeter designed to indicate dosage in röntgen units. This instrument, said to be the first of its kind of wholly British manufacture, is a portable quartz-fibre electrometer, constructed for operation from 230V 50 c/s and is supplied complete with three thimble ionisation chambers. The "Victrometer" incorporates a clearly scaled and illuminated graticule calibrated directly in röntgen units, and a simple, viewing system, ensuring precise measurement of radiation intensities at all voltages normally used for superficial, intermediate and deep X-ray therapy. Suitable uses for the instrument are the measurement of radiation output from gamma ray sources, and the calibration of other dosage instruments in hospital departments, university and industrial laboratories and similar establishments.

Department of Scientific and Industrial Research

Among the Associations represented on the D.S.I.R. stand are : The British Iron and Steel Research Association ; The British Scientific Instruments Research Association ; The Welding Research Association ; The Fuel Research Association and the National Physical Laboratory ; The British Coal Utilization Research Association and the Hydraulics Research Station.

The British Scientific Instrument Research Association is demonstrating a photoelectric indexing servo-mechanism designed for the control of machine tool movements. It is arranged to act as a follower, actuated by a master of glass or metal and it can be used to control the table of a drilling machine or the tool saddle of a lathe.

The Welding Research Association is showing a catenary galvanometer designed for the recording of small temperature variations determined by means of small thermocouples. It is designed as a storing galvanometer. The sensitivity is enough to give full-scale deflection with a temperature range of ±0·5 deg. Cent. and, when the conditions are such that damping is unimportant,

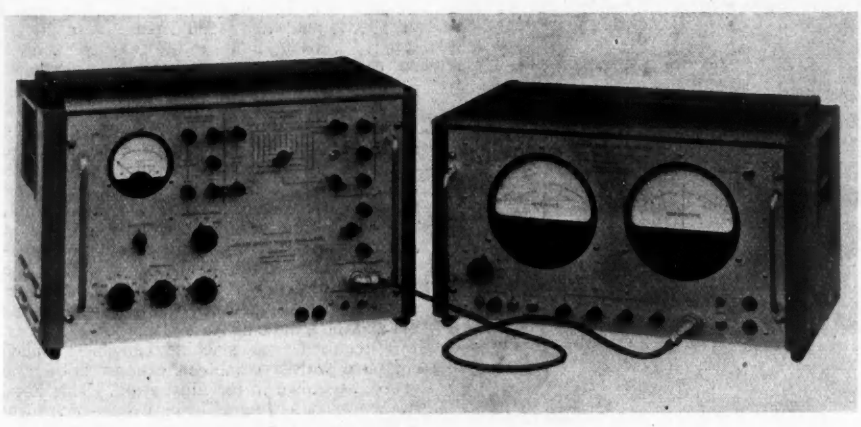


Fig. 4—Transfer function analyser ; phase measuring equipment for testing servo mechanisms—Solartron

the instrument can readily detect currents of 10^{-9} *A*.

The Hydraulic Research Station is exhibiting a free-running rotary flow meter which is designed for measuring water velocities down to 0·6 cm per second. It makes use of miniature propellers (made of plastics) which rotate under flow conditions, the rotation being measured by an electronic pulse counting and timing unit.

The National Physical Laboratory exhibits include a feedback dynamometer for measuring current, voltage and power and a pneumatic gauging head for the precision measurement of bores.

The feedback dynamometer is a portable dynamometer used with two feedback amplifiers, one of which supplies current to the moving coil, the other to the fixed coil. The amplifiers are operated with a common input when the instrument is used as a voltmeter or ammeter.

The pneumatic gauging head for bore measurement consists of a head which locates automatically within the bore in such a way that its anvils contact opposite ends of a diameter. The movement of the anvils varies the escape of air from an orifice in a conventional pneumatic circuit. A sensitive pressure indicator in the circuit is calibrated to give direct readings of variations in diameter.

The N.P.L. is also showing a steerable beam ultrasonic flaw detector, in which the ultrasonic beam can be deflected by using a square piezo-electric plate divided into strips as a transducer and feeding the sections with delayed signals. By using different delays and switching five different beam positions can be obtained.

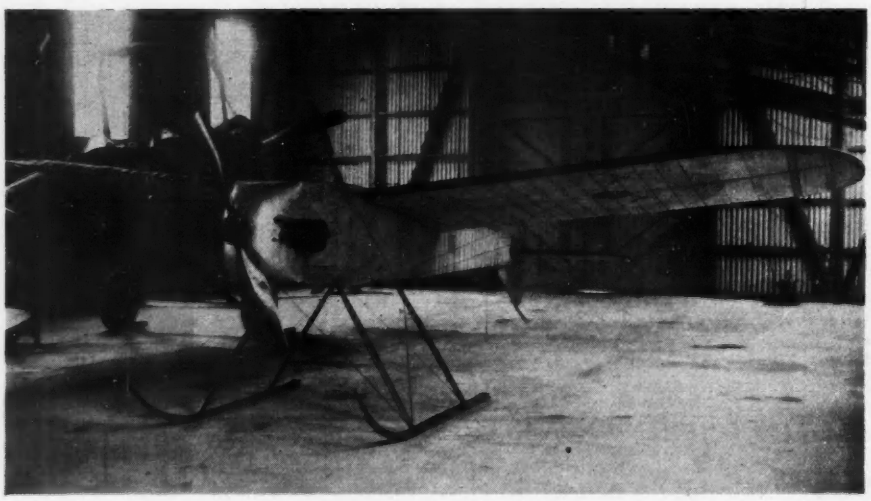
Another N.P.L. exhibit is a torsional wave delay for computing machines. It demonstrates the principle that by using torsional waves in storage devices the storage capacity can be increased. The example shown has a delay of about 4 milliseconds and ferrite transducers are used to store pulses about 1¼ microseconds long. This kind of delay is cheaper to produce and easier to maintain than the usual mercury delay line.

(*To be continued*)

Control Gear of Guided Missile

LAST week, at a short ceremony, Professor A. M. Low presented to the Imperial War Museum, Southwark, London, the original control gear of the world's first guided missile which made the first radio-guided flight under selective control on March 21, 1917. It was in May, 1914, that Professor Low demonstrated the principles of T.V. and from 1914 onwards development work on control gear went forward, the original gear being derived from the experimental T.V. apparatus. The control gear, after many experiments, was built in a garage at Chiswick, and later all personnel transferred to a hangar at Brooklands, where, assisted by Commander Brock, Captain Poole, Captain Bowen and Mr. Whitton, the experiments to build a missile were carried out. A missile in the form of a monoplane was constructed using a pair of "S.E.5" biplane wings attached to a fuselage of circular section and using as a power unit a "Gnome" radial engine. No launching gear was provided and control was by means of a large induction coil, but although not flown the unit was tested at the Central Flying School at Upavon. These early experiments held out prospects of success and directly influenced the establishment of the Royal Flying Corps Experimental Works at Feltham, Middlesex, under the command of Major Low. Here the first "aerial target," as it was designated, was built.

This was a de Havilland monoplane equipped with means for steering, controlling the engine and exploding the war head by a system of locks which prevented outside interference. Our photograph shows a model of the monoplane used in the trial flight of March 21, 1917. It consisted of a box section fuselage and a 10 h.p. horizontally opposed air-cooled engine and had the aerial wrapped round the wings and body. The servo control or actuating gear for controlling the ailerons and rudder was placed in the forepart, while the selective receiver was fitted on a resilient mounting in the middle of the body. This equipment, which was radio controlled and designed to give selective closing of particular circuits, operated on the principle of a time switch which rendered interference from extraneous signals almost impossible. The exact time of transmission of the signals was keyed by a letter-lock system and the time could be varied, while a "pecker" gear ensured that unless each signal was composed of an exact number of signals, exactly spaced, there was no final contact. The transmitter had keys marked "up," "down," "left," "right," "half speed" and "explode," which, when pressed, enabled the correct series to be sent and so guide the missile. For high control speeds an electrically operated gyroscope was designed and experiments went forward to discover a method of transmitting messages back from the missile to the control, so that the missile could be controlled when out of sight. At the trial the missile was launched from an inclined ramp by means of a multiplying gear driven by compressed air. The folding launching ramps, the compressor, the generator for the power for radio transmission and other gear were readily transportable in a 5-ton lorry. Another item presented was a model of a wireless-controlled rocket missile designed to pursue enemy aircraft. The rocket has a deflecting cowl and gas outlet apertures at the fore end and two vanes, rotatable about axes at right angles to one another, at the rear end. Polarised magnets under electrical control actuate the vanes to give directional control.

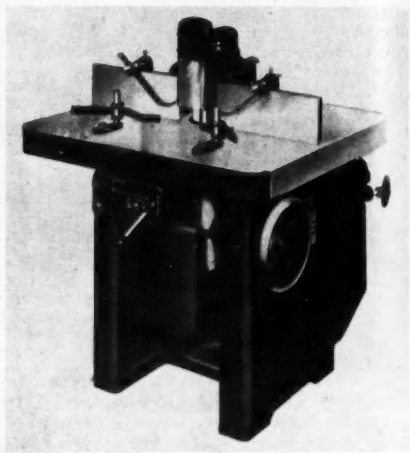


Model of radio-controlled monoplane used in trial flight on March 21, 1917

Spindle Moulding Machine

A NEW design of spindle moulder introduced by Thomas Robinson and Son, Ltd., Rochdale, is illustrated below. This machine has a loose spindle mounting which enables the spindle to be quickly and easily removed although it is firmly locked whilst running. A single hand lever only is used to control the machine and this lever moves in a gate with positions for running, stopping, locking, braking the spindle and an intermediate neutral setting. A further point in the design of the new machine is the use of a drive in which the belt tension is proportional to the load on the cutter-block.

The 37in by 33in table has wide machined clamping ledges on the right and left underside edges to facilitate the use of jigs or clamps, and is provided with tapped holes for the fitting of fences, &c. A set of four concentric table rings provides for various cutter diameters and these rings can be turned over for their raised reverse sides to be used as guide flanges. The yoke in which the cutter spindle is mounted in ball bearings has a vertical adjustment of 6in through a handwheel fitted with a locking device.



Spindle moulding machine with single hand lever control

The spindle is driven through an endless flat belt by a 4 h.p. motor which is carried on a hinged mounting in such a way that a movement takes place to increase or reduce the belt tension in proportion to the load applied to the cutter spindle. The control lever which starts and stops the motor is in such a position that, without need for releasing the workpiece in his hands, the operator can move the lever to stop the motor and apply the brake by means of his knee. A heavy duty or a light duty cutter spindle can be fitted as required to the machine.

The heavy duty spindle is provided with two speeds through a cone pulley on the motor—4100 r.p.m. and 6500 r.p.m. on a 50 c/s supply or 4950 r.p.m. and 7900 r.p.m. on a 60 c/s supply. The light duty spindle has two speeds of 5300 r.p.m. and 8500 r.p.m. on a 50 c/s supply, or 6450 r.p.m. and 10,300 r.p.m. on a 60 c/s supply. The end of the spindle is bored to take detachable spindles for carrying different kinds of cutter-blocks and cutters, and when required these can be removed as complete assemblies without disturbing the set-up. The detachable spindles have parallel shanks with large diameter collars and are held down on the main spindle by a cotter and a lock nut. The heavy duty detachable spindle top is 1¼in diameter and the distance between the underside of its nut and the spindle flange is 8in. The light duty detachable spindle top is ¾in diameter and the distance between the underside of its nut and the spindle flange is 4¼in.

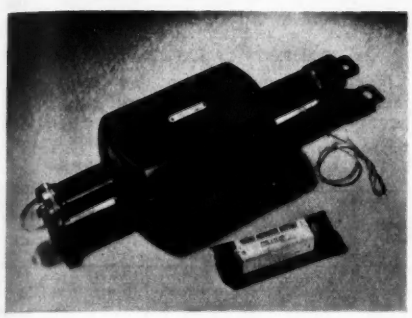
If required, the machine can be supplied complete with a combined exhaust hood and guard, as shown in the illustration. This hood has a transparent panel in its front which gives a clear view of the spindle and is adjustable for height.

Water-Activated Batteries

A RANGE of water-activated storage cells has been developed by Chloride Batteries, Ltd., Swinton, Manchester, for "one shot" and emergency applications, such as the provision of current for illuminating life saving apparatus at sea. These cells (one of which is illustrated here) are designed to give sufficient power to light small electric lamps on life jackets, floats and rafts to facilitate rescue work when a ship or aircraft is lost at sea after dark.

For such duties the cells are required to be small and light and to remain reliable despite years of idleness in all climatic conditions.

A typical water-activated cell consists of special dry-charged plates of cuprous chloride which remain completely inert so long as they are protected from moisture by sealing tape or some similar means. In an emergency the cell is easily made operative by ripping off the tape; then, as soon as the plates come into contact with the water, whether salt or fresh, the battery



A lifebuoy light and a water-activated battery suitable for use with it

becomes energised. The cell can be designed to operate either whilst it is totally immersed in water for the duration of its discharge, as in the case of flares or life jacket lights, or after an initial wetting, during which sufficient water will be absorbed to activate the cell.

Various sizes and capacities of water-activated cells have been developed by Chloride Batteries, Ltd. Most of them make use of cuprous chloride and magnesium electrodes. The smallest cell works on a somewhat different principle using lead peroxide and magnesium electrodes, and is intended to replace the candles once carried by meteorological balloons. With its bulb it weighs less than half an ounce; after the cell is dipped in water and attached to the balloon the lamp will burn for more than 45 minutes.

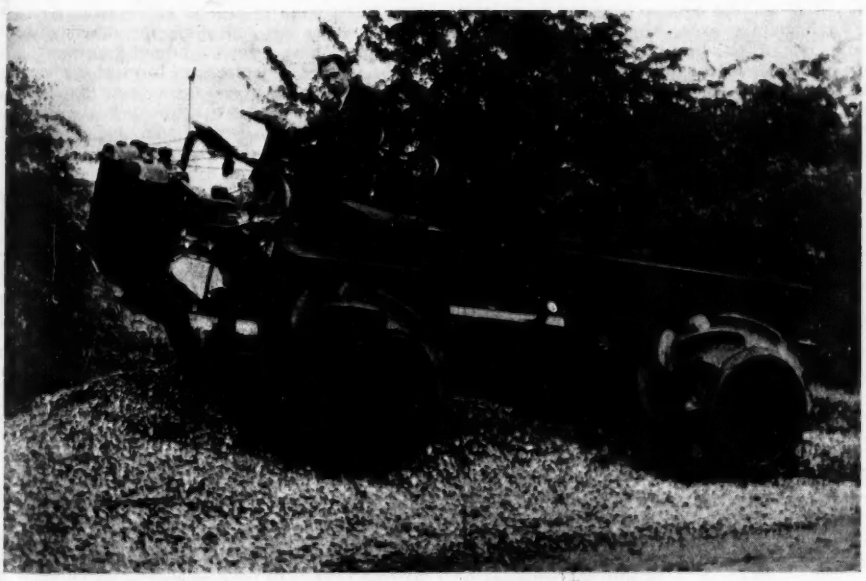
Two intermediate sizes using cuprous chloride/magnesium electrodes have been produced for "Mae Wests" and other air/sea rescue equipment. When sewn into the life jacket, the cell illuminates a 1·5V bulb consuming 0·24W mounted on the shoulder. The smaller of the two sizes, weighing only 2¼ oz in its experimental container, will burn for 12 hours and the larger, weighing 4 oz, for 24 hours. The fourth and largest of the water-activated batteries in the commercial range, intended for life-saving rafts and floats, will illuminate a 2·5V 2W bulb for at least 24 hours. Another version has been specially designed for a lifebuoy light manufactured by Venner Electronics, Ltd. We learn that larger cells with a capacity of 200Ah have also been developed.

Cross-Country Vehicle

WE illustrate on this page a demonstration model of a cross-country vehicle which is built by Nicholas Straussler and Co., Ltd., 5, Clarges Street, London, W.1. Its design and the use of the firm's "Lypsoid" tyres are stated to give the vehicle a particularly high performance when used on very bad terrain.

The vehicle is powered by two engines arranged transversely in line on the frame in front of the front axle. Either two four-cylinder petrol or two four-cylinder diesel engines are fitted and they are connected by a bevel gear drive to the clutch and gearbox shaft. With two petrol engines the total horsepower installed can be 150 or 180 and with two diesel engines 90 h.p. or 120 h.p. The gearbox gives five forward and one reverse speeds, and the number of speeds available is doubled through a two-speed transfer box. Both axles are normally driven, and if required for light running purposes, either of the two engines can be disconnected through the two-speed transfer box. This box also incorporates means for disconnecting the drive from the front axle and a drive for a winch.

The chassis has an all-up weight of 3 tons 5 cwt and with a loaded weight of some 6 tons the unit ground pressure is only 4½ lb. The vehicle is fitted with 44in diameter by 28in wide "Lypsoid" tyres which each have a contact area of 800 square inch in soft ground. In cross-section these tyres form a large arc, the proportions of which are such that, under load, the crown of the arc bends inwards into an inverted pan shape. The wheel rims grip the heavily reinforced beads of a tyre and the angular deflection of the carcase under load is small. A low air pressure of 10/15 lb per square inch is used with the tyre and this permits large deformation inwards when passing over such things as rocks or stones. On soft terrain this inwards deformation of the tyre compacts the soil and thereby increases considerably its shear resistance.



Cross-country vehicle arranged for single or twin-engine drive

Continental Engineering News

Jochenstein Power Station

After two and a half years' work on the German-Austrian Danube power station of Jochenstein, the first Kaplan turbine of 39,000 h.p. and its 28,000kW generator were put into operation on April 16th. The turbine, built by J. M. Voith G.m.b.H., Heidenheim (Brenz), is designed for a consumption of 350 cubic metres per second at a differential of 9·6m. At present a differential of only 8·1m has been reached, and as a consequence the output is reduced to 20,000kW. Since April, two further turbine sets have been completed. The alternators were built by A.E.G., Berlin, Siemens, Berlin, and Elin, Weiz/Steiermark.

European Inland Waterways

Problems concerning the inland waterways of Europe were discussed at a meeting held recently at Geneva under the auspices of the United Nations Economic Commission for Europe (E.C.E.). This conference was the first of its kind to be held since the war, and provided an opportunity for the representatives of all interested governments and international organisations to exchange views and suggest solutions of outstanding questions. These comprised the unification of police regulations, standardisation of signs and signalling systems, registration of vessels, transport of dangerous goods, standardisation of boatmen's certificates and ships' papers, the contract for river transport and the problem of waterway pollution.

While it was realised that complete unification of police and navigational regulations was impossible owing to differences in the characteristics of the waterways, the Secretariat was asked by the conference to make a comparative study of existing regulations, in order to enable individual governments to decide what changes within their own areas were desirable and practicable.

While documentation is already uniform on some of the main river systems such as the Rhine and most of the Danube, the conference decided that a more complete unification was desirable, especially on interconnected systems, and the Secretariat was instructed to prepare a study of this question.

A group of experts from the Permanent International Association of Navigation Congresses is already working on the unification of signs and signals on some waterways, and following this conference, the group will extend its activities to those countries which until now have not taken part in this scheme. When approved, the experts' recommendations will be submitted to the governments concerned by the E.C.E. Inland Transport Committee.

Conventions for unifying the rules about collisions and the registration of vessels were originally drawn up in 1930 under the League of Nations. They were never put into force, but are now to be revised and completed by a special working party. Recommendations were made for the drawing-up of a convention regarding the carrying of dangerous goods.

Water pollution is becoming more and more serious in many countries. An example is the Netherlands, where only a small proportion of the available water is suitable for agriculture, stock breeding or horticulture.

Not only is the increasing industrialisation leading to greater quantities of traditional toxic materials being dumped into rivers and canals, but there is the possibility of an additional danger from new materials, such as atomic waste products, for which no ordinary methods of purification may exist. Since many interests are affected by this question, it was decided that it could not be dealt with adequately within the framework of the Inland Transport Committee. A proposal for an international centre to study the problems relating to water pollution is to be examined by E.C.E.

Lastly, the meeting agreed that it was desirable to implement a unified convention regulating relations between carriers and senders, such as has for long existed on the railways. A procedure was agreed for finalising a draft recently prepared by the International Institute for the Unification of Private Law.

Performance Tests on Indentors for Rockwell Hardness Testing*

By R. S. MARRINER

To establish a standard of hardness using the Rockwell principle it is necessary to know to what extent hardness values are affected by the choice of indentor. Direct comparison of a few results from different indentors can be misleading, as the local variations of the test blocks used and variability of the testing machine affect such comparisons. Details of a method of eliminating these sources of variability from the results are given and some additional sources of performance difference, such as the orientation of the crystallographic axes of the diamonds, are discussed.

IN the measurement of hardness by indentation it has always been appreciated that truth of form of the indentor is a basic requirement, and this is recognised in the stringent specification given in the British Standard B.S. 891 : 1940 for the diamond indentor prescribed for tests using the Rockwell principle. The manufacture of indentors to the British Standard is not easy and experience at the National Physical Laboratory indicates that few indentors satisfy all the tolerances laid down. In addition, measurements made at the Laboratory have established the presence of an error of form which is not covered in the Standard, and which is likely to influence the performance of an indentor. It is therefore not surprising to find in the literature references to the variability introduced by the use of different indentors.

In current industrial operations it frequently happens that a very rigid specification of hardness is laid down and difficulties are encountered in maintaining an adequate standard of hardness. At present, the only practicable scheme for ensuring a uniform standard of hardness throughout industry appears to be the use of calibrated test blocks, but this translates the onus to those responsible for supplying the blocks or to those organisations which undertake their calibration. It is obviously desirable that such organisations should be in agreement not only nationally, but also internationally, and it is unfortunate that, at the international level, the agreement is at present not satisfactory. In seeking the causes for the discrepancies which exist, particularly amongst those institutions which possess deadweight hardness testing machines, it quickly becomes evident that differences in the indentors used may be a prime factor.

Experience at the National Physical Laboratory in the calibration of hardness test blocks by means of a deadweight testing machine has shown very clearly how important is the form of the indentor : differences in performance were found even with indentors conforming very closely to the British Standard. To establish an irreproachable standard of hardness it clearly became necessary to determine to what extent reproducibility of the standard is limited by the choice of indentor used for making the indentations and the present article describes some preliminary work which has been carried out at the Laboratory with this object in view.

Investigation of the differing performance of indentors can be resolved into three stages, viz.:—

(1) Precise measurement of hardness values given by each of a group of indentors at various levels of hardness.

(2) Determination of the precise geometric and structural differences between the indentors used.

(3) Correlation of (1) and (2) to achieve a specification which would result in the production of indentors for calibration work whose performance could be predicted.

Stage (3) can only follow from (1) and (2), but so far little work has been done on the differences in structure of the diamonds used in indentors or the precise orientation of their crystallographic axes, which, as will be seen later, may affect their performance. However, the work carried out at the National Physical Laboratory by Tolmon, Wood and Hall[1] on the measurement of the form of indentors by interferometry has made it possible to group indentors into those having no appreciable departures from the ideal geometric form and those having larger but known departures.

As regards (1) above, the measurement of the difference in performance of two indentors is hampered by the fact that two indentations on a test block cannot be made at the same time and at the same spot on the block. In practice, at some stage of the comparison the indentors must be interchanged in the machine and the indentations must be made at different points on the test block. Hence observed differences in hardness number cannot be attributed to the indentors alone, since they will be influenced by the random variations due to indentor mounting, the performance of the machine and local variations in hardness of the test block.

To obtain a precise estimate of the effect due to differences in the indentors, it is necessary to make the effects due to test block and machine as small as possible in comparison with that due to the indentor, and further, to ensure that any systematic effects are common to the different indentors. This problem of isolating one source of variation from other variations has been solved in many ways in other fields and one solution, that of the Græco-Latin square design of experiment, lends itself admirably to the problem of hardness testing. Using a deadweight Rockwell hardness machine, this design of experiment has been used to determine the performance difference between seven indentors at six levels of hardness and to measure systematic effects such as the lubrication of the test block, method of mounting, &c. Details of the design and analysis of the results of these experiments are discussed in this article.

Design of Experiment

Indentors.—For the principal tests seven indentors, obtained from three different manufacturers, were used. Designating letters and relevant data concerning these indentors are given in Table I.

Table I

Manufacturer	Identification of indentor	Departure of angle from nominal	Departure of spherical tip from nominal form	Surface finish	Circularity of cone		Displacement of cone axis from nearest crystallographic axis
					Departure from circle	Form	
		(minutes)	(in)		(in)		
1	*A*	+4	Nominal within ±0·00005	Very good	0·0005	4 lobed	9 deg. from (110)
1	*B*	+2½	Nominal within ±0·00005	Very good	0·0008	3 lobed	12 deg. from (111)
1	*C*	−7	Nominal within ±0·00005	Very good	0·0005	3 lobed	10 deg. from (111)
1	*G*	−15	Nominal within ±0·00005	Very good	0·0003	3 lobed	6 deg. from (111)
2	*F*	+7 to +14	0·0001 excess	Very good	0·0006	4 lobed	10½ deg. from (100)
3	*X*	+21 to +26	Nominal within ±0·00005	Poor	0·0004	4 lobed	—
3	*Y*	+17 to +24	0·0001 excess	Poor	0·0004	Elliptic	—

Notes :
1. The nominal cone angle and radius of the spherical tip for these indentors, as given in B.S. 891 : 1940, are 120 deg. and 0·2mm (0·008in), respectively.
2. The departure from circularity, column 6, is defined as the difference in diameter of two imaginary co-planar concentric circles such that the annular space between them would just contain the profile of the surface under test.
3. Examination of interferograms of these indentors showed that the tip of indentor *F* was sharp and wedge-shaped and the blend of the spherical tip with the cone was poor in comparison with the other indentors.

No precise information about the source of the diamonds used in these indentors was available although it was known that fundamental differences existed because their appearance under ultra violet light varied. Indentor *A* fluoresced red while the others either fluoresced bluish green or did not fluoresce.

The marked differences in form of the cones suggested that the cone axes were differently related to the diamond structure and accordingly X-ray photographs were made of five of the indentors. They showed that the tri-lobed indentors had their cone axes nearer to an axis of three-fold symmetry (111) than to any other axis. Fig 2 shows diagrammatically the projection of the crystallographic axes on a plane perpendicular to the axis of the cone together with the measured out-of-roundness of the cone. It will be seen from Fig. 2 that the lobes of the tri-lobed sections correspond with the direction of the projected (100) axes. (The indentors *X* and *Y*, which had been borrowed from abroad for the hardness measurements, were not available for the X-ray examination.)

Test Blocks.—The six test blocks used covered the range H_RC 28 to H_RC 67 and the results of six random indentations made on each by the manufacturer indicated that they were uniform in hardness to H_RC 0·2 for the hard blocks and to H_RC 0·5 for the soft blocks.

Arrangement of Indentations.—The arrangement of the indentations was dictated by the possible sources of systematic error which would affect the comparison of the indentors. These sources of systematic error are as follows :—

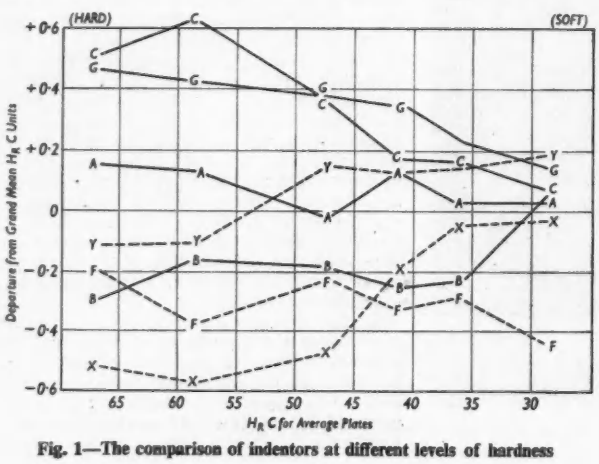


Fig. 1—The comparison of indentors at different levels of hardness

* Communication from the National Physical Laboratory.

(i) In a run of a large number of indentations there might be a small but systematic drift in the performance of the machine.

(ii) After clamping an indentor in the machine the first few indentations are often unreliable as the indentor appears to " seat itself " under load. Hence a systematic error which can be assigned to the order of indentation may be introduced.

(iii) A possible non-uniformity of hardness of the test block which might take the form of certain bands in the surface being harder or softer than other bands. Such a condition could arise through a failure to quench and temper uniformly.

In addition to these sources of systematic error, random errors arise from local variations in hardness of the test blocks and small variations in the performance of the machine whilst loading. To minimise or isolate these sources of error the following scheme was adopted.

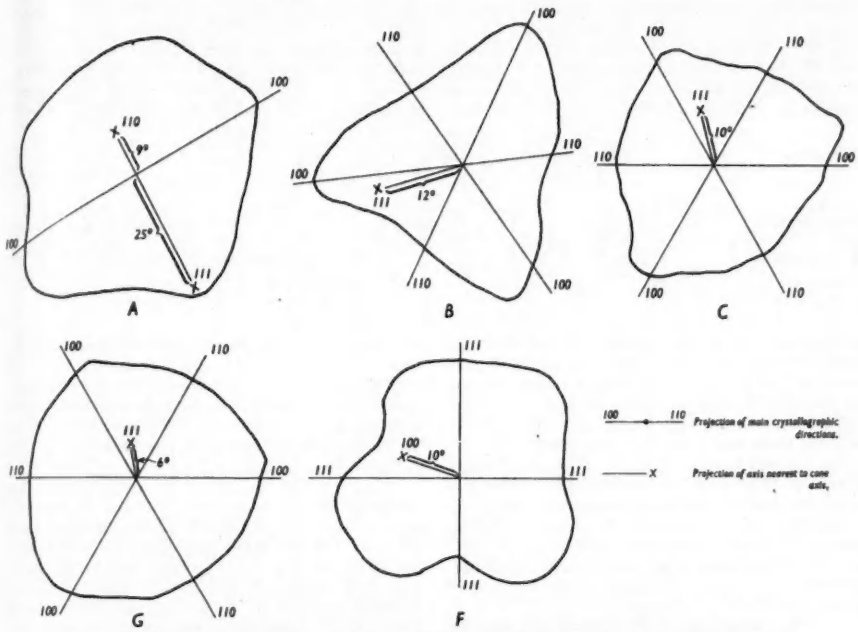


Fig. 2—Out-of-roundness of cones (magn. 1000) and orientation of crystallographic axes

Consider one of the test blocks. Each of the seven indentors was used in turn to make seven indentations on it. The forty-nine indentations so made were arranged in seven rows and seven columns (compare Table II), the rows and columns being spaced 0·2in apart. The positions of the seven indentations produced by any one indentor were so arranged that one occurred in each row and one in each column. In addition, it was arranged that of the seven first test indentations made after mounting each indentor, one occurred in each row and column. The seven second test indentations were disposed similarly and so on. (It should be noted, however, that in all cases three dummy indentations were made near the edge of the block immediately following a change of indentor. These indentations were not part of the Græco-Latin Square.)

A typical arrangement is shown in Table II where the letters designate the indentors, the numbers the order of indentation, and the rows and columns the corresponding positions on the test block. Such an arrangement is known as a Græco Latin Square.

TABLE II

Row	Column						
	1	2	3	4	5	6	7
1	*G2*	*B3*	*C6*	*Y5*	*F1*	*A7*	*X4*
2	*F4*	*X7*	*G5*	*A3*	*C2*	*Y1*	*B6*
3	*C7*	*Y6*	*F2*	*B4*	*G3*	*X5*	*A1*
4	*A6*	*G1*	*X3*	*F7*	*Y4*	*B2*	*C5*
5	*B5*	*A2*	*Y7*	*C1*	*X6*	*G4*	*F3*
6	*X1*	*F5*	*A4*	*G6*	*B7*	*C3*	*Y2*
7	*Y3*	*C4*	*B1*	*X2*	*A5*	*F6*	*G7*

All forty-nine indentations were made on one block before going to the next, and the order in which the indentors were used was random and different for each block.

The consequence of this arrangement is that, for each block, the mean of the results in any column comprises a result from:

(*a*) Each indentor
(*b*) Each order of indentation
(*c*) Each row

and hence comparison of column means is unaffected by any systematic error arising from indentor, order of indentation, or row. Similarly the mean of the results from any one indentor is independent of systematic errors from the three other sources and an unbiased comparison of indentor effect can be made.

Results of Experiment

To present the indentor effect clearly the hardness number for each plate was assessed as the grand mean of all forty-nine indentations. This grand mean was then substracted from the mean value for each indentor and the resulting departures were plotted against the average for each plate as shown in Fig. 1. It will be seen at once that:

(1) Indentor *F* is an outsider in that its performance does not agree with the other indentors at low levels of hardness. Reference to the note at the foot of Table I shows that its tip is sharp and inferior as regards form to the others. A sight of the interferogram of the tip is uncompromising in its rejection of this indentor.

(2) The performance of indentors *C* and *G* differs markedly from that of *X* and *Y*; the former give departures which are positively correlated with hardness while the latter are negatively correlated (i.e. the slope of the plots for *C* and *G* are different in sign from those for *X* and *Y*). Reference to Table I reveals three differences between these indentors, viz. manufacturer, cone angle, and surface finish, and any one of these may account for the observed difference in performance. The manufacture of the indentor may affect its performance by the particular methods used for cutting and fixing the diamond in its mount and by the particular orientation of the crystallographic axes.

(3) Indentors *A* and *B* although made by the same manufacturer as *C* and *G* behave quite differently, but reference to Fig. 2 shows that indentor *B* is markedly tri-lobed and this feature may directly account for its increased penetration.

Complete correlation between the results given in Fig. 1 and the factors displayed in Table I is not possible at this stage as the indentors used have insufficient factors in common.

Analysis of Results

Before discussing further experiments, it will be useful to consider what additional information can be obtained from the Græco-Latin design. As stated above, before the observed performance differences can be regarded as real it is important that these differences must be large in comparison with the random variations in hardness value introduced by local variations in the test block and possible irregularities in performance of the dead weight machine. If this is not so, a repeated trial might show that the apparent difference between two indentors has disappeared or even reversed. The method of demonstrating that the observed differences are real and that test block and machine variability is negligible is as follows.

Each of the forty-nine hardness values for each block may be regarded as composed of the sum of

(1) The true average value of the block.

(2) An effect due to the particular indentor used.

(3) An effect due to the order of indentation, i.e. whether it was the first, second, or third, &c., indentation.

(4) An effect due to the particular row in which the indentation lies being harder or softer than average.

(5) A similar effect due to the column in which it lies.

(6) A random effect due to a local variation in hardness of the block, together with any random variation in the performance of the machine caused by ambient temperature change, external vibration, &c.

The total variation, or, more precisely, the variance, of the forty-nine observations is obtained from the sum of the squares of the departure of each observation from the grand mean. This total variance can then be broken down into the variance which arises from each of the effects detailed in (2) to (5) above and a residual variance due to the random effects of local irregularities of hardness of the block and vagaries of the machine's performance.

The ratios of the variances due to (2), (3), (4) and (5) to the residual variance (called *F* ratios) are compared with standard tables to ascertain whether the indentor, order, row, and column effects respectively are real, i.e. sufficiently large in comparison with the random effects to exclude the possibility that they have occurred by chance. In the experiment described above the indentor variance was, for all test blocks, extremely high in comparison with the residual variance in the order, row and column effects negligible.

A worked example with formulæ is given in the appendix (page 58) to show the breakdown of the total variance and the comparison of the *F* ratios with the tabulated values.

Having removed the variance due to indentors, orders, rows and columns from the total variance the residual variance can be used for two purposes. In the first place it gives a measure of the accuracy of the results for each indentor. For the experiment described it shows that the results plotted in Fig. 1 may be relied on to $\pm H_R C$ 0·15 with 95 per cent confidence, i.e. one in twenty of the results plotted may be in error by as much as $H_R C$ 0·15, but the majority will be well within this value.

In the second place it gives a measure of the reliability of the experiment as a whole. For example, if for one of the six test blocks used a residual variance was obtained many times greater than for the other five, the uniformity of hardness of the block or the performance of the machine while indenting that block would be suspected even if the results for the indentors appeared to conform with the results for the other blocks. This use of the residual variance as a measure of the precision of an experiment led to two further experiments.

Additional Experiments

(1) This experiment was designed to determine the effect of different methods of mounting the indentor in the deadweight machine and different methods of applying the load. To achieve this, six Græco-Latin square arrangements were superimposed on one test block, i.e. each indentation of each square was displaced a small distance from each indentation of the previous square. The indentations comprising a square were made under different conditions of mounting the indentor and operating the machine. From the results of each square was obtained an average

TABLE III

Method of moving load	Method of mounting indentor	Mean hardness value	Residual variance
		(H_RC units)	(H_RC units)
Hydraulic ...	Co-axial draw screw	64·69	0·018
Hydraulic ...	Loose in an adaptor which was rigidly held by a draw screw	64·57	0·023
Hydraulic ...	Co-axial draw screw	64·70	0·031
Mechanical	Co-axial draw screw	64·16	0·050
Mechanical	Co-axial draw screw	64·27	0·064
Hydraulic ...	Held in the adaptor by a side set screw	63·24	0·077

value for the hardness of the test block and a residual variance as shown in Table III.

The results in Table III are shown plotted in Fig. 3 and it will be seen that hardness value and residual variance are highly correlated. Further, it is known that the conditions of working when the low residuals were obtained were superior to those resulting in high residuals. The smooth action of a hydraulic lift for changing the load

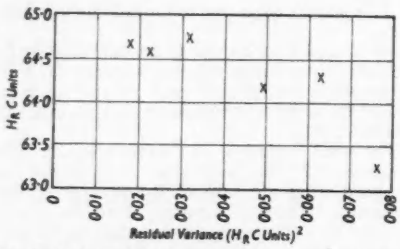


Fig. 3—Relationship between residual variance and mean hardness value

as compared with a mechanical lift reduced the residual variance and, similarly, clamping the indentor in a direction co-axial with the axis of the cone by a draw screw threaded into the end of the shank as compared with clamping the indentor by a side set screw also reduced the residual variance and increased the value of hardness obtained. It is interesting to note that these results confirm the general impression among observers that in a set of observations higher values are the more reliable whilst low values indicate that the machine is not giving of its best.

(2) This was a double experiment carried out to

(*a*) Determine the effect of grease on the test block.

(*b*) Compare the performance of a deadweight standard machine with a commercial machine employing a lever system.

Two sets of indentations were made on a test block using the deadweight machine in the manner described above. The first set was made with the block clean and dry and the second with the block smeared with vaseline. A third superimposed set was made using a lever system machine with the same indentors and the test block clean. The whole experiment was repeated with a second test block of different hardness.

The results were as follows. The mean hardness difference between the indentations made on the clean dry block as compared with the greased block were $H_RC+0·03$ and $H_RC-0·01$ for the two test blocks. Neither of these differences is significant with regard to the residual variance and it is concluded that grease on the surface of the test block does not affect the hardness value obtained. A direct comparison of the residual variances from the two machines showed that results from the deadweight machine were twice as reliable as those from the other machine. In fact, if the appreciable variance due to local variation in hardness of the test blocks were known and was removed from the residual variances then the accuracy of the deadweight machine would appear even higher in comparison with the other machine.

At present it is not possible to separate variation in hardness value due to the machine from that due to local variations in the test blocks. An indication that the latter is appreciable for some test blocks is that, in the analysis of variance, the row and column effect referred to above is sometimes significantly high in comparison with the residual. The fact that the average hardness along or across a standard test block can vary appreciably implies that there are probably equally large localised variations.

CONCLUSIONS

(1) The most important conclusion derived from the experiments described herein and other experiments of a similar nature carried out at the Laboratory is that the greatest source of variation in hardness values lies in the different performance of the indentors, particularly at the higher levels of hardness. Until all the causes of performance difference are isolated and controlled the level of hardness given by any machine will be dependent upon the indentor used.

(2) The application of the Græco-Latin square design of experiment to the hardness problem is a sure method of isolating the sources of variation of hardness values, and provides a means of comparing the performance of different indentors and of different machines, the consistency of performance of a single machine or the uniformity of hardness of test blocks.

(3) The performance of an indentor may be influenced by any one of the following properties :

(i) Geometrical form, which includes radius and truth of form of the tip, cone angle, blending, and out-of-roundness of the cone.

(ii) Surface roughness.

(iii) Structure of the diamond, including its hardness.

(iv) Orientation of the crystallographic axes to the cone axis.

(v) Method of manufacture and fixing of the diamond in its mount.

The experiments carried out so far on the lines described in this paper have not indicated that any one of these properties has a paramount influence on the performance. To ascertain the relative importance of the various factors further investigations on similar lines are being pursued.

The author desires to acknowledge the comments and suggestions he received from his colleagues in the Metrology Division, National Physical Laboratory. The work described above has been carried out as part of the research programme of the National Physical Laboratory, and this article is published by permission of the Director of the Laboratory.

APPENDIX

The indentations on one test block were made in the order and positions displayed in Table II. The results in H_RC units less H_RC 66 are given in Table IV. For example, the second indentation with indentor *G* was made in row 1, column 1 and gave a hardness value of H_RC 67·66, which is recorded as 1·66 in Table IV. The subtraction of the constant H_RC 66 lightens the computation considerably and does not affect the final results as the analysis is concerned with the variation in hardness value and not the absolute value.

Row X_R, column X_C, indentor X_I, order X_O,

TABLE IV

Row \ Column	1	2	3	4	5	6	7	Row totals
1	1·66	0·82	1·76	1·12	1·22	1·56	0·67	8·81
2	1·12	0·77	2·01	1·46	1·81	1·46	0·92	9·55
3	1·76	1·17	1·17	1·07	1·96	0·87	1·27	9·27
4	1·46	1·76	0·77	1·07	1·37	1·02	1·91	9·36
5	1·12	1·51	1·17	2·16	0·72	1·76	1·22	9·66
6	0·87	1·17	1·56	1·76	1·12	1·76	1·02	9·26
7	1·12	1·66	1·12	0·92	1·51	0·97	1·51	8·81
Column totals	9·11	8·86	9·56	9·56	9·71	9·40	8·52	64·72 Grand total
Indentor totals	*A* 10·33	*B* 7·19	*C* 12·82	*F* 7·94	*G* 12·42	*X* 5·59	*Y* 8·43	
Order totals	1 9·86	2 9·11	3 9·11	4 9·21	5 9·71	6 8·76	7 8·96	

and grand *X* totals are computed and entered as shown.

If there are n^2 indentations and the value of any indentation is given by x then the total variation and its resolution into the variation due to each of the factors concerned is computed as shown in Table V.

The *F* ratios in column 6 are obtained by dividing the mean squares (column 5) for (*b*), (*c*), (*d*) and (*e*) respectively by the mean squares for (*f*). These *F* ratios are compared with values for 6×24 deg. of freedom obtained from standard tables. The standard values for this example are 2·51 for 5 per cent significance level and 3·67 for 1 per cent level. It will be seen that in this example the variation in hardness due to the indentors is highly significant in relation to the residual variation, whilst that due to orders, rows and columns cannot be regarded as real.

TABLE V

Source of variation 1	Formula 2	n^2 times sum of squares (using formula) 3	n^2 times degrees of freedom 4	Mean squares column 3 ÷ column 4 5	*F* ratios 6
(*a*) Total variation	$n^2\Sigma x^2 - X^2$	342·9788	$n^2(n^2-1) = 49 \times 48$	—	—
(*b*) Variation due to indentors ...	$n\Sigma X_I^2 - X^2$	307·9144	$n^2(n-1) = 49 \times 6$	1·0473	77·58
(*c*) Variation due to orders	$n\Sigma X_O^2 - X^2$	6·6400	$n^2(n-1) = 49 \times 6$	0·0226	1·67
(*d*) Variation due to rows	$n\Sigma X_R^2 - X^2$	4·6044	$n^2(n-1) = 49 \times 6$	0·0157	1·16
(*e*) Variation due to columns	$n\Sigma X_C^2 - X^2$	7·9154	$n^2(n-1) = 49 \times 6$	0·0269	1·99
(*f*) Residual variation	$a-(b+c+d+e)$	15·9046	49×24	0·0135	—

Standard *F* tables and further information concerning the analysis of Græco-Latin squares can be obtained from statistical textbooks dealing with analysis of variance.

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[2] "Further Developments in the Precision Measurement of Diamond Indentors for Rockwell Hardness Testing," Tolmon, F. R., and Hall, Joyce, F, *Engineering*, 1954, 178, 760.

SEARCH FOR NATURAL GAS.—It is announced by the Gas Council that a second deep well is to be sunk in the area near Crowborough, Sussex, in connection with the search for natural gas in this country. The site of the second well is about 1 mile south-east of the first well, and work there is likely to begin in the next few weeks and to continue for about four or five months. The first well in the area was carried down to a depth of about 4500ft and revealed small shows of gas at several levels. The results obtained from that well and subsequent seismic surveys in the area have now been studied by the technicians of the D'Arcy Exploration Company, which is undertaking the work on behalf of the Gas Council, and it is considered that a further deep test is justified.

Nuclear Power Station for New York

BY OUR AMERICAN EDITOR

EARLIER this year, the Consolidated Edison Company of New York, Incorporated, announced its intention of building a nuclear steam-electric power plant, to be known as the Indian Point Station at Buchanan, New York, on a site 24 miles north of New York City on the east bank of the Hudson River. This was the first announcement made by an American utility company indicating its readiness to proceed, without Government aid, since the passage by Congress of the Atomic Energy Act of 1954 opened up the possibility of the development of nuclear steam generating stations by private capital. An application for a licence to build this plant was filed with the U.S. Atomic Energy Commission in March and it is expected that the installation will become "critical" in the autumn of 1959.

The accompanying illustrations show the preliminary heat balance sheet and a general layout of the proposed power station. The nuclear steam generator will be designed and built by the Babcock and Wilcox Company and is an assembly of a nuclear reactor and a recirculating high pressure coolant system to remove the heat generated in the reactor and to transfer it to boilers. The boilers, in turn, remove the heat from the coolant by generating steam. The reactor is of a design known as a pressurised water thorium-uranium convertor. It consists of a large cylindrical vertical steel tank which is partially filled with shielding water and contains a small vessel in which the core is placed. The core of the reactor consists of a geometrical pattern of closely spaced fuel elements which contain the nuclear fuel. The basic fuel is enriched uranium, i.e. uranium containing a higher amount of uranium-235 than natural uranium as mined from the earth. Uranium-233, which also serves as a fuel, is obtained by the conversion of thorium-232 into uranium-233 within the reactor itself. The fuel elements will be protected by a corrosion resistant material designed to prevent the coolant water, which passes over the element surfaces, from becoming contaminated with radioactive fission products. Control rods, which start and stop the reactor and regulate the amount of heat produced, are arranged within the fuel elements and are positioned by remote hydraulic or electrical means. The coolant system consists of four pipe loops operating off the reactor core and serves both to absorb the heat generated in the core and to deliver heat to the boilers. Each loop consists generally of pumps, a boiler, shut-off valves and inter-connecting piping. The pumps will continually circulate the coolant water at a pressure of about 1500 lb per square inch. The coolant flow is equally divided in these loops and the steam generated by each boiler is fed to a steam header.

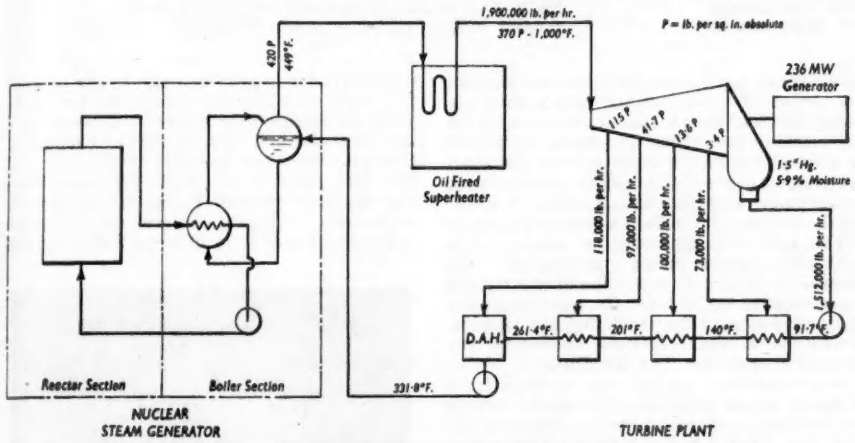


Fig. 1—Preliminary heat balance sheet of proposed Indian Point power station

Each boiler will consist of two major components—the boiling section and a separate steam drum. The boiling section consists of "U" shaped stainless steel tubes, the ends of which are welded into heavy tube sheets, enclosed in a steel shell. The coolant flows through the inside of the tubes. The steam generated from the water surrounding the "U" tubes will rise to the steam drums through pipes, where it will be dried by passing through a conventional steam separator. The non-radioactive steam will leave the drum at 420 lb per square inch absolute, in the saturated condition. All surface in contact with primary coolant water will be made of stainless steel since the coolant water is quite corrosive, and all components will be designed to minimise leakage of the radioactive coolant. Each of the four boilers, with their loop pumps and coolant pressure controls, will be housed in a large horizontal steel container. Each of these containers will be vented to the vertical vessel housing the reactor core. Since the reactor and the primary cooling system are radioactively "hot" while in operation, the entire steam generator and its auxiliaries, in addition to being housed in steel containers, will also be enclosed within a thick dense concrete shield. The top of the small vessel which contains the fuel elements will be removed periodically to replace spent fuel elements with new ones. All of the re-fuelling operations must be done remotely, for the core and the operating fuel elements, even when the unit is shut down, are radioactively "hot." On the other hand, the boilers, valves and pumps will be accessible for inspection or repair within a very short time after the reactor is shut down. Adjoining the reactor will be a deep, water-filled tank in which the spent fuel elements will be stored. After a storage period, the spent fuel elements will be put into thick-walled lead containers and then will be conveyed to a Government processing plant where the unburned part of the fuel will be recovered.

To provide for greater economy, and to produce higher temperature steam which will permit the use of a standard steam turbine, the saturated steam from the nuclear steam generator will be passed through a separate oil-fired superheater, and will supply steam to the turbine throttle at a pressure of about 370 lb per square inch absolute and a temperature of 1000 deg. Fah. The use of such superheated steam will facilitate an increase in electrical output of the turbo-generator of 96MW, as compared with the output obtainable when feeding saturated steam to the turbine. As a result the power station is expected to have a capacity of 236MW and an overall heat rate of about 10,700 B.Th.U. per kilowatt-hour net.

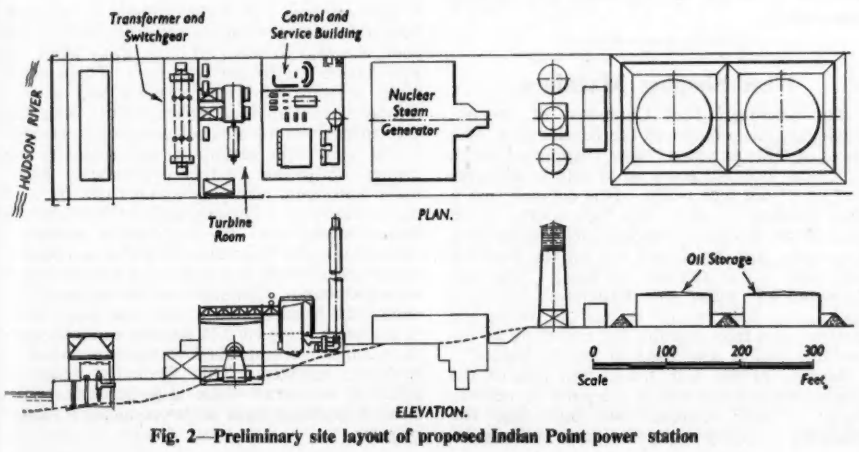


Fig. 2—Preliminary site layout of proposed Indian Point power station

High-Speed Coin-Weighing Machine

THE National Bureau of Standards, Washington, D.C., recently developed a fully automatic machine for weighing coins rapidly at the request of the U.S. Department of the Treasury. The machine can weigh and sort 18,000 coins per hour with an accuracy of 0·25 per cent in the weighing of 25-cent pieces and with even greater accuracy in the weighing of larger American coins. The system applied has the advantages of high sensitivity, low susceptibility to seismic noise, and independence of other physical properties of the coin except diameter which, however, is held to extremely close tolerances in manufacture. The machine is much faster than the automatically fed analytical beam balance now in use at the U.S. Mints.

The present weighing system used by the American Treasury consists in dropping the coin into a basket suspended from the beam of an analytical balance and allowing the beam to some to rest. The beam is then clamped and the coin is ejected into either a high or a low chute. This process takes about four seconds. A limitation on improving the response speed of the balance is the ratio between the mass of the beam and the comparatively small differential mass of the coins, since the small mass will not accelerate the large mass rapidly. The new machine weighs coins by measuring the degree of unbalance imparted to a rapidly revolving flywheel into which two coins, the standard and the one to be weighed, have been placed. If the flywheel is precisely balanced initially, the difference in weight between the two coins will displace the centre of gravity slightly from the geometric centre of the wheel. The detection of this displacement provides the basis for measuring the weight of the coin. A method has also been developed for injecting the coin into the rapidly moving flywheel and removing the coin after it has been weighed. The sorting of coins into "light" and "heavy" categories is accomplished by means of suitable circuitry which determines precisely the angular position of the wheel at which the coin is to be removed so that it will fall into the proper container.

The system employed is essentially a pen-

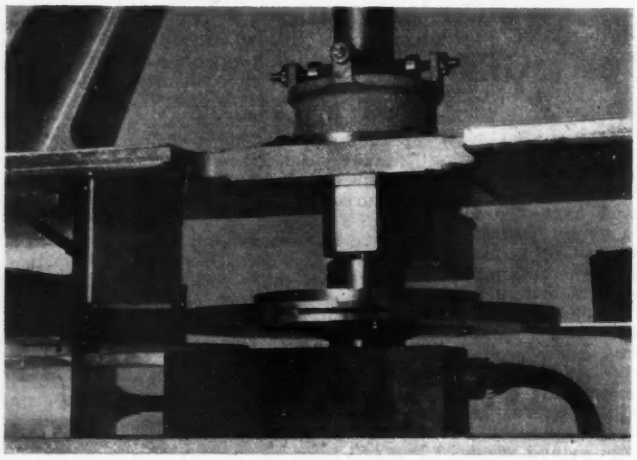


Fig. 1—Flywheel of N.B.S. coin weighing machine with coin inserting mechanism (below wheel) and stroboscopic light (above wheel) used in balancing wheel dynamically

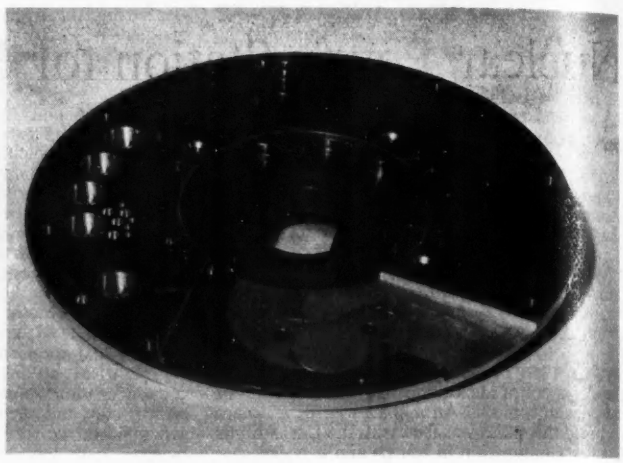


Fig. 2—Coin weighing flywheel with coin in holding pocket and standard weight inserted at point diametrically opposite coin

dulum whose principal mass is concentrated in a flywheel approximately 7in in diameter. As shown in Fig. 1, the wheel is mounted at the lower end of a vertical rotating shaft. At the top of the shaft is a gimbal mount which serves as the fulcrum and a d.c. motor which turns the weighing wheel at 3000 r.p.m. The pendulum is of such a length that its natural period is much longer than the period of vibration established by the revolving wheel. Thus, the vibrational effects of the wheel are independent of any resonant effect of the pendulum and the rotation of the centre of gravity of the wheel about its geometric centre takes place as though the wheel were a body revolving in free space. By rotating the wheel at 3000 r.p.m., with the coins placed at a distance of about 2¼in from the centre of the wheel, an acceleration of nearly 500 *g* is imparted to the coins, thus magnifying the small weight differential between them 500-fold. The vector product of the large synthetic acceleration and the small differential mass is the force which causes the wheel to accelerate rapidly into a new orbit about its new centre of gravity whenever a coin of unknown weight is placed in the wheel. Within six revolutions of the wheel, the initial transient disturbance resulting from the loading of a new coin into the periphery of the wheel while it is rotating is damped down. Since the wheel is revolving at 3000 r.p.m., these six revolutions take only 0·12 second. The subsequent detection of the constant amplitude of vibration which determines the difference in weight between the two coins is made during the two following revolutions. A total of ten revolutions is allowed for the complete weighing cycle ; thus five coins can be weighed each second.

An electronic mutual-inductance micrometer probe placed near the wheel hub detects the vibration of the pendulum shaft. This device is an extremely sensitive transducer which can determine a change in length as small as 50 micro-inches and can accurately measure the few thousandths of an inch displacement in the weight-indicating vibration. The transducer consists of two co-planar, co-axial coils wound on a dielectric core. The primary coil is energised from a regulated r.f. source whose frequency is much higher than the wheel vibration frequency. The mutual inductive coupling between the primary and secondary varies as a nearby conducting material—i.e. the wheel hub—moves toward or away from the coil assembly. When the wheel vibrates, the secondary coil generates a modulated a.c. signal whose period is equal to that of one revolution of the wheel. The transducer, with its regulated power supply and simple amplifier, produces a signal of relatively large amplitude which has a linear relation to the departure of the coin from the nominal weight. The response speed is more than adequate to meet the requirements of this application.

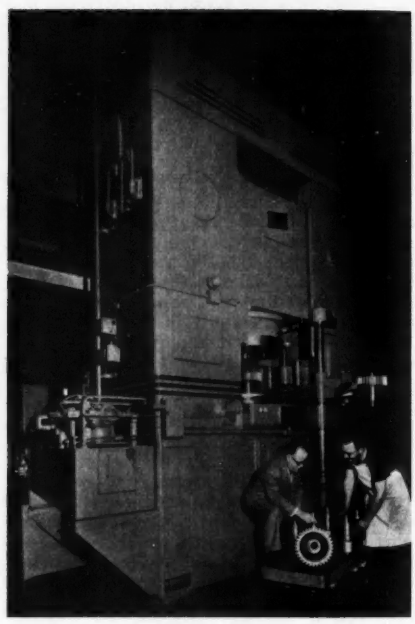
The coin to be weighed and the standard coin lie on a straight line which passes through the geometric centre of the wheel. If the coin to be weighed is heavier or lighter than the standard, the centre of gravity of the pendulum moves along this line to one side or the other of the geometric centre. Thus, the wheel can vibrate in either of two modes which are 180 deg. apart with respect to the time at which the coin in the wheel passes a given point. A mirror mounted on the rotating shaft reflects a beam of light on to a photo-cell, thus generating an electrical pulse each time the coin passes a given point. The photo-cell signal coincides with either a positive or a negative signal from the transduc r once each revolution of the wheel, and the combination of the two signals indicates whether the coin is heavier or lighter than the standard.

An interesting method was developed for injecting a new coin into the rapidly moving flywheel and at the same time removing the coin that has already been weighed. The coin is initially inserted into the wheel by a poly-iron core solenoid which injects the coin vertically upward into a hole in the bottom of the hub. A condenser, which is charged to 800V, supplies the energy for the injecting pulse. This pulse, when applied to the solenoid, produces a powerful eddy-current magnetic repulsion field between the coin and the core, thereby lifting the coin into the hole. The axis of the hole in the hub is inclined at a small angle to the axis of the rotating spindle and directs the coin into a position that is slightly away from the geometric centre of the flywheel. Subsequently, centrifugal force causes the coin to move into the pocket at the periphery of the wheel, as shown in Fig. 2. The new coin imparts its kinetic energy to the weighed coin that is already in the pocket, thus forcing this coin off the wheel. By properly controlling the time at which the new coin is inserted into the wheel, the eject phase position is so chosen that the weighed coin may be cast into an " accept " or " reject " receptacle. The timing is electronically determined by the weight of the coin in the wheel. The addition of a relatively small amount of electronic circuitry provides a means of balancing the flywheel dynamically.

Gear Shaping Machines

THE Michigan Tool Company, of Detroit, Michigan, has announced the development of a series of " Shear Speed " gear shaping machines which can produce gears up to 20in in diameter and up to 6in face width. It is claimed that a 20in diameter, 3 D.P., 6in face width, which takes three hours to produce on conventional equipment, can be turned out on the machine illustrated within thirteen minutes. The unit is equipped with an automatic hydraulic positioning hoist which is used to swing the cutting head into position for mounting in the machine and is also used to handle blanks.

Because of the high production rate of the equipment and the size of the parts to be produced, a chip conveyor was built into the machines to carry away the large volume of metal chips removed from a part in one production cycle. For instance, one of the first parts to be machined on the shapers is a cluster gear for a manufacturer of earth-moving equipment. The gears are 12½in and 6½in in diameter and have face widths of 3½in and 5½in, respectively. The diametral pitch of the gears is 2½ and 2, respectively. Shaping one gear on this cluster will produce over 15 lb of chips within six and



" Shear-Speed " high-production gear shaping machine

a half minutes. A large volume of coolant flow is directed not only to keep the cutting tools cool, but also to wash all chips away from the part fixture on to the conveyor. Three automatic pressure lubricating systems feed a continuous flow of oil to all moving parts. A special detecting system warning bell notifies the operator if the vital ram section is not receiving the proper lubrication. Either hydraulic or pneumatic automatic clamping fixtures can be used on the machines. The operation of the clamping fixture is tied into the completely automatic machining cycle. The cutting heads here are readily interchangeable to accommodate different part sizes and shapes. The stroke of the reciprocating work ram is adjustable to suit the face widths of the gears being cut. A complete tool change-over can be accomplished within twenty-five to forty-five minutes. This flexibility makes it practical to operate these large machines on a batch production basis while producing a variety of parts.

Industrial and Labour Notes

Coal

This week, the annual conference of the National Union of Mineworkers is being held at Rothesay, and last Tuesday the delegates were addressed by Sir Hubert Houldsworth, chairman of the National Coal Board.

Sir Hubert surveyed the coal situation and spoke about the way in which the National Coal Board was attempting to deal with the many problems confronting it. He emphasised that both the Board and the union must recognise that the nationalised coal industry had a duty to coal consumers. The union, Sir Hubert suggested, had no right to fight for the nationalisation of the industry unless it was prepared, subject to the proper safeguarding of its members interests, to co-operate in making the industry successful. He then commented on the fact that this year the industry had already lost over 2,000,000 tons of coal by unofficial strikes and "go slow" periods. That, he said, was as great a challenge to trade union leadership as it was to the leadership of the National Coal Board. Certainly, Sir Hubert continued, shortage of manpower hindered production of coal, but that shortage must not be allowed to excuse hindrances to production which could be removed. When all manpower, administrative, technical and manual, was short, none of it must be wasted in any way, and all restrictive practices, however hallowed they might be by tradition, should be removed. Such practices, Sir Hubert emphasised, could not be justified on any grounds.

There never was a time, Sir Hubert continued, when it was more necessary to harness at the pit level the co-operation and skill of the union with the endeavours of the Coal Board. Without doubt, an increase in co-operation between management and men at many pits could produce an immediate increase in output. If, Sir Hubert added, the same good relations prevailed at all pits as they did at the national level, and generally at the coalfield level, and at many pits, there could be an immediate improvement in output.

Costs and Prices

At a meeting of the National Production Advisory Council, which was held in London last Friday, the Chancellor of the Exchequer, Mr. R. A. Butler, gave another warning that industry must achieve and maintain a competitive level of costs. He said that although our exports had been going up our competitors had also been doing better.

If costs and prices in this country were allowed to rise faster than those of the U.S.A. and Germany, the Chancellor continued, this country would have to accept the consequences of a reduced share of world trade and a check to its hopes of a steady rise in the standard of living. The country must ensure that the growth of its economy did not take place at the expense of the exports needed to maintain that growth. That meant, the Chancellor said, that demand at home must be carefully watched, and that credit control and other measures restricting demand must be applied with the courage and resolution which the situation required. Then, Mr. Butler added, it was essential that we actually sold abroad the goods we had made available for export. To do that, he emphasised, industry was going to need something more than expanded production and selling drive. It must achieve and maintain a competitive level of costs.

Referring specifically to the subject of competitive costs, the Chancellor mentioned that, since 1950, labour costs in Germany's manufacturing industries had been stationary. At the same time they had risen by an annual average of 2 to 3 per cent in the U.S.A. and by twice as much in this country. He went on to say that, in the United Kingdom, the index of rates of wages for May was 7 per cent above the 1954 average. It would require, the Chancellor commented, a really large and sustained rise in productivity to offset the rise in wages and the present upward pressure on costs and prices.

End of the Dock Strike

Last week-end there were meetings of dock workers in London, Manchester, Liverpool and Hull, which recommended a resumption of work following a strike, of nearly six weeks' duration, called by the National Amalgamated Stevedores and Dockers' Union. The union has been pressing a claim for representation on joint negotiating bodies concerned with matters affecting the northern ports.

The Transport and General Workers' Union is represented on the negotiating bodies, and the disputes committee of the Trades Union Congress has ruled that the National Amalgamated Stevedores and Dockers' Union has no claim to representation. The stoppage of work, in which some dockers in the Port of London have also participated, thus arose from an inter-union dispute, and could not really be said to relate to conditions of employment. At times during the past six weeks, however, as many as 20,000 men have been idle at the affected ports and many ships have consequently been seriously delayed.

The serious effects of the strike upon the country's overseas trade were referred to by the Minister of Labour, Sir Walter Monckton, Q.C., in a speech at Bristol last Saturday. Sir Walter said that overseas trade in motor cars, cycles, tractors, farm machinery, and electrical equipment had been affected by the strike. Some overseas buyers were already cancelling orders, and those in the buying markets abroad would soon lose confidence in the ability of this country to deliver the goods. Even with the immediate end of the strike, Sir Walter added, it would take a considerable time before work at the docks became normal.

Careers in Civil Engineering Construction

An illustrated brochure, entitled "Chance for a Lifetime," has been produced by John Laing and Son, Ltd., to emphasise the opportunities now available to youths to make a career in civil engineering construction. Construction, the brochure says, means the shaping and patterning of a new world, and it has, therefore, an urgent need of the enthusiasm and "adventurousness" of young people. The building and civil engineering industry, it is pointed out, is continually developing and equipping itself with new techniques, materials, methods and machinery to match the complexity of present-day demands.

The brochure goes on to give some details of the history of John Laing and Son, Ltd., and makes references, accompanied by illustrations, to several of the more important works which the firm has carried out in recent years. The latter part of the brochure contains particulars of the firm's five-year pupilage scheme for public and grammar school boys, and also gives information about the opportunities open to university graduates.

Changes in Wage Rates

Figures published in the *Ministry of Labour Gazette* show that the changes in wage rates reported to have come into operation in the United Kingdom during May resulted in an aggregate increase of £365,000 in the weekly full-time wages of about 961,000 workpeople. Among those who received wage increases in May were manual workers employed by local authorities in England, Wales and Scotland, non-skilled workers paid at miscellaneous rates in many Government industrial establishments, workers in brickmaking in England and Wales, building and civil engineering contracting workers in Northern Ireland, and workers in the vehicle building industry.

The non-skilled workers in Government industrial establishments received increases in the minimum rates amounting to 3s. a week for men and 2s. 6d. a week for women; in brickmaking in most districts of England and Wales the minimum time rates were increased by 2½d. an hour for men and 1½d. an hour for women, and in building and civil engineering contracting in Northern Ireland there were increases of 2½d. an hour for craftsmen and 1½d. an hour for labourers. In the vehicle building industry the increases were 3d., 2½d. or 2d. an hour, according to occupation, for men, and 2d. an hour for women.

The Ministry says that in the first five months of this year, changes in wage rates resulted in an aggregate increase of £3,870,500 in the weekly full-time wages of about 9,890,500 workers. In the comparable period of last year the aggregate weekly increase was £2,151,000 for 6,639,000 workpeople. At the end of May this year the index of rates of wages (June 30, 1947=100) stood at 152 for all workers, compared with 142 a year earlier. So far this year, the index has moved up six points.

Time Rates of Wages and Hours of Labour

The Ministry of Labour has now published the ninth edition of a booklet entitled "Time Rates of Wages and Hours of Labour," the figures given in it being those applicable at April 1, 1955. The main tables show, for the more important industries and occupations in the United Kingdom, the minimum or standard time rates of wages and the dates from which they became operative, and also the normal hours of labour.

The rates of wages and the hours of labour tabulated in the booklet are those fixed by voluntary agreements made between organisations of employers and workpeople, by joint industrial councils or other similar bodies, or by statutory orders under the Wages Councils Acts. Particulars are also included, where available, of the basic rates for pieceworkers, the additional rates payable to shift and night workers, and, where they exist, the arrangements for guaranteed weekly wages. In three appendices there are set out details of rates of wages for young workers in a number of industries, and of overtime rates and arrangements for paid holidays in the industries given in the main part of the booklet.

The booklet, which costs 7s. 6d., is obtainable from H.M. Stationery Office.

Trade Disputes

The Ministry of Labour has stated that during the month of May 257 stoppages of work through industrial disputes were reported in the United Kingdom. In addition, nine stoppages which had begun earlier were still in progress at some time in the month. In these 266 stoppages of work, the Ministry says, 201,500 workers were involved directly and indirectly in May, and there were 838,000 working days lost.

In April there were 199,000 days lost by 67,900 workpeople on account of stoppages through disputes, and in May last year there were 111,000 working days lost by 29,200 people. In May this year the biggest loss of working days, 581,000, occurred through stoppages in the coal mining industry. The May figures also include, of course, the loss caused in the early part of the strike of British Railways' locomotive men and of the dock workers' strike. These losses are shown under the heading of transport, in which seven stoppages were reported during May, the number of workers involved being 70,100 and the number of working days lost being estimated at 206,000.

It is stated that in the first five months of this year, 1068 stoppages of work through industrial disputes were reported to the Ministry of Labour. They involved 401,500 workpeople and caused an aggregate loss of 1,427,000 working days. In the comparable period of last year there were 912 stoppages reported, involving 186,600 workpeople and resulting in a loss of 623,000 working days.

Personal and Business

Appointments

MR. T. A. DUNCAN has been appointed London director of Croggon and Co., Ltd.

THE CONSOLIDATED PNEUMATIC TOOL COMPANY, Ltd., announces the appointment of Mr. C. L. Fisher to the board of the company.

MONSANTO CHEMICALS, Ltd., states that Dr. J. W. Barrett, general manager of the research and development division, has been appointed a director.

MR. W. H. MORTON has joined the board of Catton and Co., Ltd., steelfounders, Leeds, as sales director. Mr. E. D. Wells has been appointed technical sales manager.

THE MINISTRY OF TRANSPORT AND CIVIL AVIATION announces the appointment of Sir John Gibson Graham as freight market representative, in succession to the late Mr. H. O. Roberts.

MR. E. S. COX has been appointed mechanical engineer (development) on the British Railways central staff, in which capacity he will act as deputy to the chief mechanical engineer.

LONDON TRANSPORT states that Mr. W. P. Morgan, chief administrative assistant to the operating manager (country buses and coaches), has been appointed divisional superintendent, northern division.

MR. R. E. G. WEDDELL, joint managing director of W. G. Allen and Sons (Tipton), Ltd., has been elected president of the Institute of Welding. Sir Charles Lillicrap has been elected vice-president.

RICHARD SUTCLIFFE, Ltd., Horbury, Wakefield, announces the appointment of Captain E. O. F. Price, R.N. Ret., as London area manager. His office is at 325, Vauxhall Bridge Road, London, S.W.1.

MR. P. J. C. BOVILL has been appointed to the board of directors of Newton Chambers and Co., Ltd. The managing director, Sir Harold West, is to retire next year, and Mr. Bovill will eventually succeed him.

MR. A. C. WOOLARD and Mr. E. NICHOLSON have been appointed to the sales staff, at Plymouth and Huddersfield respectively, of Brook Motors, Ltd. Both served their apprenticeships in the company's works.

MARTONAIR, Ltd., Parkshot, Richmond, Surrey, announces the following appointments :—Mr. C. D. P. Smallpeice and Mr. G. Godwin, joint managing directors ; Mr. R. C. Cartwright, director and secretary, and Mr. C. Kirk, technical director.

GENERAL REFRACTORIES, Ltd., Genefax House, Sheffield, announces the appointment of Mr. B. Eichler as director of research (silica and aluminous division), and Mr. H. Parnham as director of research (basic division) at the Central Research Laboratories, Worksop.

THE ENGLISH ELECTRIC COMPANY, Ltd., states that Mr. D. G. Welton has left the Stoke-on-Trent sub-office to take up an appointment in the company's London office. Mr. R. Edwards, formerly of the Birmingham branch office, has been appointed to take charge of the Stoke-on-Trent sub-office.

PROFESSOR A. J. MURPHY, M.Sc., F.I.M., who for the past five years has been Professor of Industrial Metallurgy at the University of Birmingham and Director of the Department of Physical Metallurgy and Industrial Metallurgy since 1953, has been appointed Principal of the College of Aeronautics, Cranfield, Bedfordshire.

C.A.V., Ltd., states that Mr. J. J. Brown has been appointed area sales manager for Northern Ireland and Eire. His headquarters are at 51, Upper Library Street, Belfast. Mr. R. J. Hale is the senior service engineer for both territories and Mr. H. Draper has been appointed service engineer attached to the C.A.V., Ltd., depot at Portland Street North, North Circular Road, Dublin.

MR. J. ANDERSON has been appointed a director of Vickers-Armstrongs (Aircraft), Ltd.; Rear-Admiral Sir Anthony Buzzard, Bt., and Mr. A. P. Wickens have been appointed directors of Vickers-Armstrongs (Engineers), Ltd., and Rear-Admiral Sir Anthony Buzzard, Bt., Commander M. Cunningham, and Mr. F. D. Stickland have been appointed to the board of Vickers-Armstrongs (Shipbuilders), Ltd.

SOCONY MOBIL OIL COMPANY INC., New York, announces the following appointments, consequent upon the retirement of Mr. George Holton from the office of chairman of the board :—Mr. B. B. Jennings, chairman of the board and chief executive officer ; Mr. A. Nickerson, president ; Mr. Paul V. Keyser, vice-president and director in charge of foreign trade ; Mr. Austin Foster, director and general counsel, and Mr. Lawrence King and Mr. Herman Schmidt, associate general counsel.

Business Announcements

DR. ROBERT C. KING has retired from the board of Consolidated Pneumatic Tool Company, Ltd., 232, Dawes Road, London, S.W.6.

THE FAIREY AVIATION COMPANY, Ltd., states that Mr. B. J. Hurren has relinquished his appointment as sales development manager.

F. E. WEATHERILL, Ltd., has moved its office and works to Tewin Road, Welwyn Garden City, Herts (telephone, Welwyn Garden 4221).

AVELING-BARFORD, Ltd., announces the formation of a new subsidiary, Aveling-Barford Africa (Pty.), Ltd., with its head office in Johannesburg.

VACUUM OIL COMPANY, Ltd., has formed a South Wales industrial division with its headquarters at Cardiff. Mr. A. Peck is the divisional manager.

THE PLESSEY COMPANY, Ltd., announces the formation of a new subsidiary entitled The Amar Tool and Gauge Company, to handle the tool and gauge manufacturing activities at the Amar Works, Chadwell Heath, Essex.

SKIL ENGINEERS, Ltd., has been formed to manufacture the equipment formerly known as the "MRE" profile turning roller box and the "MRE" radius attachment. The address of the company is Reynold Works, Chell Street, Longsight, Manchester, 12.

ROLLS-ROYCE, Ltd., announces that an agreement has been concluded with the Twin Disc Clutch Company of Racine, Wisconsin, U.S.A., whereby the company is licensed to manufacture hydro-dynamic torque converter transmissions of Twin Disc design.

BABCOCK AND WILCOX, Ltd., Farringdon Street, London, E.C.4, announces the retirement of Mr. R. J. Glinn, M.I.Mech.E., after forty-four years in the company's service. Mr. Glinn has also retired from the board of the Calorizing Corporation, Ltd., which he joined in 1928.

LLOYD'S REGISTER OF SHIPPING announces that Sir Frederick E. Rebbeck and Mr. Gilbert J. Innes have retired from office as joint chairmen of the Technical Committee of Lloyd's Register of Shipping, and that Sir Philip B. Johnson and Mr. Charles Connell have been elected in their stead.

Contracts

BABCOCK AND WILCOX Ltd., the supplier of the steam plant for the original station at Calder Hall, has received an order for plant for extensions to Britain's atomic power supply system amounting to several million pounds. Under the new contracts eight steam towers each 80ft. in height, will be supplied to a new station to be known as Calder Hall "B" and two further installations totalling 16 towers, will be supplied to a power station at Chapelcross near Annan in Dumfrieshire.

THE ENGLISH ELECTRIC COMPANY, Ltd., has received an order from the Power Authority of the State of New York for two large transformers to be used for the St. Lawrence power project. A hydro-electric power station is now being erected on the St. Lawrence River jointly by the Canadian and United States authorities. For the Canadian side the English Electric Company of Canada, Ltd., is building in Toronto the water turbines to the designs of The English Electric Company, Ltd., in England. On the American side, part of the power generated will be stepped up to 115kV and part to 230kV. The transformers which the company is now to build will couple these two busbars together for the interchange of power. They have an output of 120,000kVA with a voltage ratio of 230/115kV with the windings auto-connected. A tertiary winding is provided for the supply of power at 13·8kV. They are three-phase units and the cooling is of the "OFW" type.

Miscellanea

LIFEBOAT TORCHES.—A Certificate of Approval has been granted to Chloride Batteries, Ltd., by the Ministry of Transport and Civil Aviation with respect to "Drydex" two and three-cell, rubber-covered torches, Marks 2RT20 and 3RT20, for use in lifeboats of merchant ships.

ROLE OF THE RAILCAR.—"Role of the Railcar" is the title of a booklet, published by Self-Changing Gears, Ltd., which contains a short survey of the advantages and scope of railcar operation. It discusses power/weight ratios, axle loading, operating costs, demands of long-distance and suburban traffic and includes a data sheet giving comparative figures for four trains.

DONCASTER BUILDING EXHIBITION.—A building exhibition will be held at the Technical College, St. George Gate, Doncaster, from July 11th to 16th inclusive. The exhibition will be opened at 2.30 p.m. on Monday, July 11th, by Sir Harold Emmerson, permanent secretary, the Ministry of Works. It will include displays on planning and design, schools and factories, research and training.

OBITUARY.—We record with regret the death of Mr. J. R. Magee, which occurred recently in Scotland. He was technical representative in Scotland of Armstrong Whitworth (Metal Industries), Ltd. We have also learned with regret of the death, on June 25th, of Mr. George Dean, sales manager of Fodens, Ltd., Sandbach, Cheshire. He had been in the company's service for fifty-one years.

NATIONAL CERTIFICATES IN METALLURGY.—The rules setting out the arrangements and conditions for the award of National Certificates in Metallurgy have been revised in consultation with the Iron and Steel Institute, the Institution of Mining and Metallurgy, the Institute of Metals and the Institution of Metallurgists. They have been published by H.M. Stationery Office, for the Ministry of Education, price 4d.

STRIP ROLLING MILL AT ROTHERHAM.—A steel strip rolling mill is to be built on the site of an old Roman camp at Templeborough, near Rotherham. This project has been put in hand by the Steel, Peech and Tozer branch of the United Steel Companies, Ltd. The mill is being designed to produce strip from 4in to 18in wide, with a maximum thickness of ½in down to a minimum of 0·042in. The project is expected to cost about £3,600,000.

ACCIDENTS IN THE CEMENT INDUSTRY.—The Cement Makers Federation has published the report for 1954 of its accident prevention advisory committee. The report gives an analysis of the accidents which occurred during the year, and recommends various measures for accident prevention. It is pointed out that the industry has a consistently low accident rate, but nevertheless there is room for improvement. In 1954, 424 accidents occurred, two of them fatal ; as a result 110,000 man-hours of work were lost.

RESIDUAL FUEL OIL.—Esso Petroleum Company, Ltd., has announced that in the interests of uniformity its three grades of residual fuel oil have been rebranded with effect from July 1, 1955. In the Inland and Marine Trade Schedules, the names "Esso Fuel Medium," "Esso Fuel Heavy" and "3000 Secs. Fuel" have been changed respectively to "Esso Fuel Light," "Esso Fuel Medium" and "Esso Fuel Heavy." In the schedule of bunker prices, the names "Esso Fuel Medium," "Esso Fuel Heavy" and "Esso Bunker Fuel" have been changed respectively to "Esso Marine Fuel Light," "Esso Marine Fuel Medium" and "Esso Bunker Fuel." Prices, specifications and conditions of sale are not affected.

RETIREMENT OF MR. K. C. BARNABY.—On June 30th Mr. Kenneth C. Barnaby, retired from the position of naval architect to John I. Thornycroft and Co., Ltd., but will remain as the company's honorary consulting naval architect. Mr. Barnaby joined the company as an apprentice in 1909 and later spent some time with Chantiers et Ateliers Augustin-Normand at Le Havre and with John Brown and Co. (Clydebank), Ltd., to gain experience. From 1916 to 1919 he was assistant to the yard manager and then went to a shipyard in Rio de Janeiro for a few years. Shortly after his return to Southampton he was made naval architect to John I. Thornycroft and Co., Ltd., and has continued to act in that capacity since 1924. During the last five years he has been a director of the company, and he is also a director of Red Funnel Steamers, a member of the Southampton Harbour Board, and the author of the textbook *Basic Naval Architecture*.

COOPERS HILL PRIZE AND MEDAL.—The triennial award of the Coopers Hill War Memorial prize and medal has been made by the council of the Institution of Electrical Engineers to Mr. D. McDonald, A.M.I.E.E., for his paper on "The Electrolytic Analogue in the Design of High-Voltage Power Transformers." The prize, which was founded by the members of the Royal Indian Engineering College, Coopers Hill, in commemoration of members of the college who fell during the 1914–1918 war, is awarded annually by the Institution of Civil Engineers, and triennially in turn by the Institution of Electrical Engineers, the School of Military Engineering, Chatham, and the School of Forestry, Oxford. The prize, which consists of a bronze medal, a certificate and about £20 in money, is awarded for the best paper on a professional subject published by the Institution during the period of the award, but only authors who are corporate members under thirty-five years of age are eligible.

C.E.A. POWER STATION EFFICIENCIES.—Over 750,000 tons of coal were saved in the power stations of the former British Electricity Authority during the year ended March 31, 1955, by increased efficiency of operation. The overall average thermal efficiency of the steam stations during the twelve months was 23·85 per cent, compared with 23·22 per cent for the year ended March 31, 1954. Of over 68,860 million units of electricity sent out from the steam stations in the period, more than one-quarter was provided by the twenty most efficient stations. These twenty stations had an average efficiency of 28·74 per cent, their individual efficiencies (percentage) being :—Portobello H.P., Edinburgh, 31·42 ; Stourport B L.P., Worcs, 30·83 ; Littlebrook B, Dartford, Kent, 30·49 ; Dunston B II, Newcastle upon Tyne, 29·74 ; Bromborough, Cheshire, 29·15 ; North Tees C, Middlesbrough, 29·05 ; Skelton Grange, Leeds, 28·89 ; Brunswick Wharf, Poplar, 28·70 ; Uskmouth, Newport, Mon, 28·66 ; Braehead, Renfrew, 28·59 ; Barking C, 28·48 ; Brighton B, 28·40 ; Poole, 28·31 ; Carrington, near Manchester, 28·30 ; Keadby, Scunthorpe, 28·28 ; Deptford East H.P., London, 28·06 ; Littlebrook C, Dartford, Kent, 27·93 ; Carmarthen Bay, Burry Port, 27·88 ; Huncoat, Accrington, 27·75 ; Battersea B, London, 27·71.

British Patent Specifications

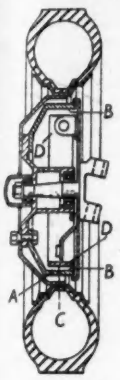
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

ROAD TRANSPORT

731,788. December 10, 1953.—RUNNING-IN FRICTION BRAKES, Daimler-Benz Aktiengesellschaft, Stuttgart-Untertürkheim, Germany.

The invention relates to a method of running-in friction brakes by assembling the part of the brake which is equipped with the brake lining together with a coacting member which differs from a normal coacting member essentially only by its possession of a greater roughness of the surface co-operating with the lining, the brake being run-in during normal road operation. Even with very irregular brake linings this method leads in the shortest time to a perfect supporting counterpart, because the running-in work is done by a pivot which substantially corresponds to the normal coacting member to be finally used. The drawing shows in a single sectional view the application of the method to the front wheel of a motor lorry. The wheel is completely and definitely assembled. The brake drum *A* has been roughened by sand blasting, before assembly, on its brake surface *B*. During operation on the road the brake lining *C* mounted on the brake shoes *D* will rapidly adapt itself to the shape of the brake drum, as the result of wear against the rough surface of such drum.—*June* 15, 1955.

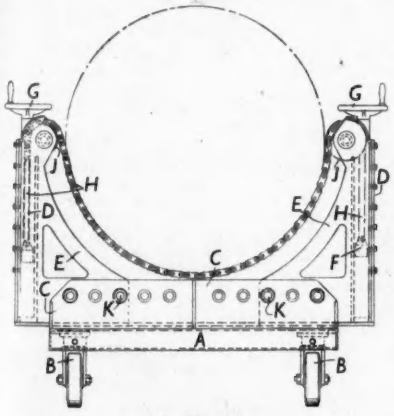


No. 731,788

MEANS OF TRANSPORT

731,968. December 11, 1952.—A BOGIE FOR HANDLING PIPES, The Ironside Engineering Company, Ltd., Gladstone Works, Gladstone Street, Soundwell, Staple Hill, Bristol; and James Walker Ironside, of the company's address.

The invention is illustrated in the drawing. The bogie comprises a rectangular frame *A* with castor wheels *B* at each corner. At each end of the longitudinal sides of the frame there is provided an upstanding member *C*, which extends across the frame and co-operates with a related inner lug member providing seating areas or mounting points for the bottom end of a tubular pillar *D* formed with a bracket-like extension *E* slidably engaged with the seating area. The interior of each pillar forms a housing and guideway for a slide *F* having a threaded passage which is engaged by an operating screw, the top end of which protrudes through the top end of the pillar and terminates in a hand wheel *G*. Secured to the slide *F* is one end of a chain *H*, which extends up the interior of the pillar and over a pulley *J* provided near the top end thereof, the chain *H* further extending transversely across the frame *A*, where it is guided over the pulley *J* of the pillar on the opposite side of the frame, its end being secured to a similar slide mounted on it. The pillars may be moved towards and away from each other transversely of the carrier and locked in position by the locking pins *K* and to positions between the ends of the carriage frame, the seatings being selected to suit working conditions. In use a pipe to be handled (indicated by dot and dash lines) is placed by crane into the cradle formed by the two chains *H* and the bogie is wheeled along to bring the pipe into the assembly position. By means of the castor-mounted frame *A* the pipe is moved axially or transversely until it is approximately in the right position. If the pipe has to be lowered or raised all the screws are rotated by the same amount by the hand wheels *G* and in the appropriate direction for paying out some more chain from the pillars or vice versa. If the pipe has to be rotated to bring the flange holes into circular register, two transversely opposite screws are simultaneously rotated in opposite directions whereby the chain is moved without the length of chain forming the cradle being altered, the movement of the chain causing the pipe to rotate. When the pipe is bolted to the existing flange the chains are lowered by rotating all screws in the same direction and the bogie is withdrawn. If it is necessary to withdraw the bogie sideways, the locking pins of the relevant pillars are withdrawn and these pillars are pivoted downward and outward into a horizontal position whilst paying out the maximum length of chain. Where it is not possible or necessary to use a crane to lift the pipe into the cradle, the bogie may comprise a frame forming an inverted U-shaped structure, which may be wheeled over a pipe lying on the ground and the chains may be slung under the pipe. Other modifications in design are also described in the specification.—*June* 15, 1955.

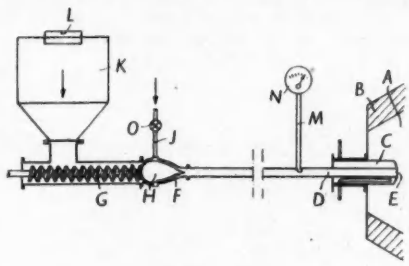


No. 731,968

GAS PLANTS

732,019. July 24, 1953.—THE GASIFICATION OF SOLID FUELS, Heinrich Koppers, G.m.b.H., 29, Moltkestrasse, Essen, Germany.

The invention refers to a process, known as the Koppers-Totzek process, for the gasification of finely divided solid fuels in suspension with oxygen or air of increased oxygen content. In the drawing *A* is the reaction space formed of fireproof built construction *B*, into which projects the mixture supply pipe *D* which is surrounded by a cooling jacket *C* at its nozzle-like mouth. At a suitable distance from the nozzle mouth *E* the mixture supply pipe *D* is connected with a mixing device *F* to which fuel dust is supplied by means of a conveyor worm *G* which passes over at the end into a pear-shaped guiding body *H*. In the intermediate space between the housing of the mixing device *F* and the guiding body *H* oxygen or air enriched with oxygen is blown in from the pipe *J*, this taking hold of the fuel dust pressed into the ring-shaped intermediate space by the conveyor worm *G* and moving into the supply pipe *D* as a homogeneous mixture. The fuel dust flows to the conveyor worm from a bunker *K*, which is shut off from the outside by a gate *L*. At a suitable point there is connected to the mixture supply pipe *D* a pressure measuring pipe *M* which leads to a pressure gauge *N* on which the pressure state in pipe *D* at any time can be read off. This pressure gauge can be connected through a suitable relay, if desired, with a shut-off member *O* controlling the oxygen pipe *J*, in such a way that at a particular change in the pressure state the shut-off valve *O* is closed and the driving motor of the worm *G* is switched off.—*June* 15, 1955.



No. 732,019

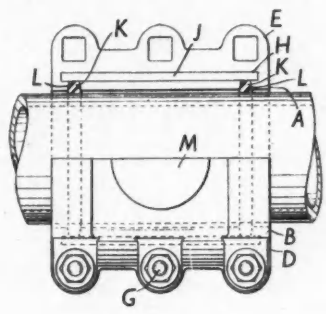
731,696. October 1, 1952.—RECOVERY OF SULPHUR FROM GASES CONTAINING HYDROGEN SULPHIDE, Heinrich Koppers G.m.b.H., Moltkestrasse 29, Essen, Germany.

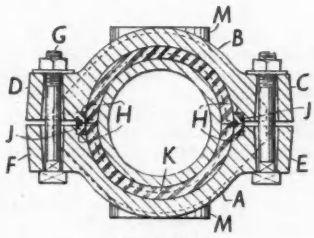
The invention relates to the recovery of elementary sulphur from gases containing hydrogen sulphide, particularly unpurified coal distillation gas. It has been found that with a temperature of 33 deg. to 35 deg. Cent. in the oxidation stage of the process the yield of elementary sulphur drops to about 65 per cent in relation to the quantity of hydrogen sulphide absorbed and that the remainder of the hydrogen sulphide is oxidised to thiosulphate, thionates, and partly also to sulphate. On the other hand, if the temperature in the oxidation stage of the process is reduced to about 20 deg. to 25 deg. Cent. or below, the yield of elementary sulphur rises to 85 to 90 per cent and in some cases even higher. The temperature of the washing liquid in the gas washing stage of the process is substantially without significance for the recovery of the elementary sulphur, but it is, however, advantageous to maintain this temperature not substantially above 25 deg. Cent. and preferably below this, as with higher temperatures the absorption of the hydrogen sulphide, particularly with the employment of ammoniacal washing solution, is poorer or requires the use of a greater quantity of liquid per unit volume of the gas containing hydrogen sulphide. Instead of carrying out cooling with the help of a cooler, in some cases direct cooling may also be carried out by allowing the washing solution to be oxidised to run over a device in which the liquid is sprinkled over a packing so as to present a large surface to the atmosphere.—*June* 15, 1955.

TUBE AND PIPE FITTINGS

731,896. August 12, 1953.—A SPLIT SLEEVE PIPE FITTING, John Ruscoe and Co., Ltd., Albion Works, Henry Street, Hyde, Cheshire. (*Inventor: Joseph Higginbottom.*)

In the repair of fractured water or gas mains, it is preferable to enclose the fractured portion with a flexible fitting rather than a rigid fitting. An object of the invention is to provide an effective fitting which is easy and comparatively inexpensive to manufacture, which consists of the minimum of parts, which is easy to fit, and in which the use of glands is avoided. From the drawing it will be seen that the split sleeve comprises two complementary half-round clip portions *A* and *B*, which are flanged at *C*, *D*, *E* and *F*. These flanges are drilled as shown, for the accommodation of securing bolts *G*. In each of the parallel faces of the flanges, and at a short distance away from the half-round part of each clip, there is provided a longitudinal groove *H*, which serves to accommodate a rubber insert *J* of square section. At each end of each clip there is provided a circumferential tapered groove *K*, and these serve to accommodate inserts *L* of rubber of circular cross section. When the clip is in position on the pipe, as shown in the drawing, the longitudinal inserts on the flanges engage one another effectively to seal the clip longitudinally. The circumferential inserts *K* in use are compressed into the grooves *H*, and in their regions adjacent the longitudinal grooves, abut the longitudinal inserts, so that the inserts, with the sleeve effectively form a water-tight or gas-tight cylinder surrounding the pipe. Each of the clip portions *A* and *B* is provided with an integral plain boss *M*. If it is desired to use the sleeve as a tee junction, then either of these bosses may be bored and suitably tapped for the reception of a branch pipe. The sleeve has been used experimentally and has been found to be extremely effective, giving adequate flexibility. In addition, tests have been performed which prove the sleeve to be both water and gas-tight up to pressures of 300 lb per square inch.—*June* 15, 1955.





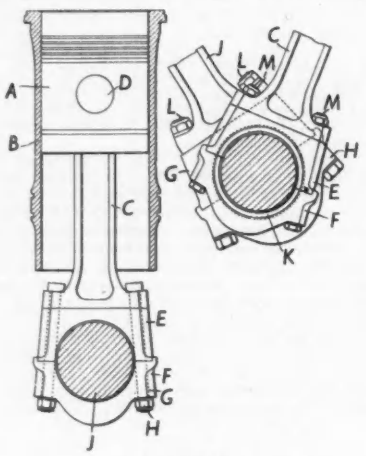
No. 731,896

INTERNAL COMBUSTION ENGINES

731,730. January 23, 1953.—BIG-END BEARINGS, The English Electric Company, Ltd., Queens House, 28, Kingsway, London, W.C.2. (*Inventor: James Millar Smith.*)

The invention relates to the big-end bearings of internal combustion engines. Referring to the left-hand view in the drawing, the piston *A* reciprocates in the cylinder *B* and is articulated to the connecting-rod *C* by means of a gudgeon pin *D*; the big-end of the connecting-rod comprises the two bearing

halves *E* and *F*, which are bolted to one another and to the connecting-rod by means of threaded bolts *G* and nuts *H*. These bolts are inclined to the centre line of the connecting-rod and the gudgeon pin *D* to that of the crankpin *J*, the centre lines of the bolts *G* converging towards the piston. Accordingly, the foot end of the connecting-rod can clear the bore of the cylinder, although thicker bolts may be used than with the usual arrangement of bolts parallel to the centre line of the connecting-rod. In the right-hand view the big-ends of a fork connecting-rod *C* and of a blade connecting-rod *J* of a "V" engine are shown. The big-end bearing *E* and



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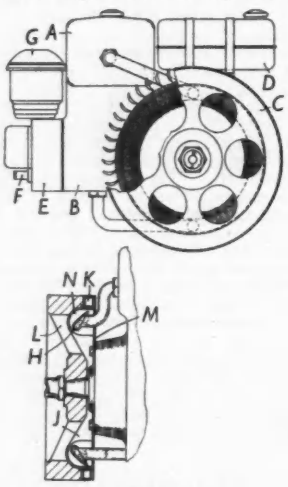
F of the fork connecting-rod *C* fits on the crankpin, while the big-end bearing *G* and *H* of the blade connecting-rod *J* fits on the outside of the bearing bush *K* and is accordingly of appreciably larger diameter than the crankpin. The bolts *L* of this bearing accordingly converge at a larger angle than the bolts *M* of the fork bearing, so as to allow the use of a foot end of the blade connecting-rod *J*, which does not substantially exceed in width that of the fork connecting-rod *C*. A modified design of bolt with spherical seatings for the head and the nut which facilitates machining and assembly is also shown in the specification.—*June* 15, 1955.

731,771. July 1, 1953.—WATER-COOLED ENGINES, Klockner-Humboldt-Deutz A.G., of Köln-Deutz, Deutz-Mulheimerstrasse, 149/155, Germany.

The invention relates to a water-cooled internal combustion engine having a cooling tower container above the engine cylinder, in communication with the cooling water jacket surrounding the cylinder, and its object is to improve the cooling. Referring to the drawing, the engine comprises a cooling water container *A* arranged above the engine cylinder *B*,



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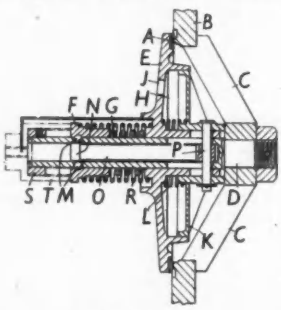
the container being in communication with a cooling water jacket surrounding the cylinder. As shown in the drawing, important parts of the internal combustion engine are a flywheel *C*, a fuel tank *D*, a cylinder head *E*, a fuel injection nozzle *F* and an intake filter *G*. The cooling of the internal combustion engine is "cooling by evaporation." The cooling water jacket and container *A* of the engine are in communication with an annular radiator *H* arranged in the region of the flywheel which runs freely in the air alongside the engine crankcase or housing, the radiator being ventilated by conveyor vanes *K* for cooling air arranged on the flywheel. The annular radiator is on that side of the flywheel which faces the engine casing, in an annular chamber *J* formed in the flywheel. As shown in the lower view, the conveyor vanes *K* for the cooling air are arranged outside the annular radiator and substantially in the same plane as the radiator. The conveyor vanes are detachably connected to the flywheel *C* and the flywheel has openings *L* for the passage of the cooling air. A protecting annular covering plate *M* is provided in the internal combustion engine adjacent to the radiator. The radiator *H* is of a drop-shaped or aerofoil tubular cross-section and it is fitted with cooling fins *N*. The invention is not limited in its application to horizontal internal combustion engines, but it can be employed in an equally advantageous manner also with internal combustion engines having different cylinder arrangements.—*June* 15, 1955.

731,863. March 18, 1953.—GAS-PRESSURE RELIEF VALVES, Bellis and Morcom, Limited, Ledsam Street Works, Birmingham 16. (*Inventor: Henry Edward Muckley.*)

The invention has for its object to provide in a simple and reliable form, a valve intended more particularly for the relief of gas pressure resulting from an accidental explosion in the crankcase of a diesel or other engine, but applicable also to other uses. Referring to the drawing there is provided an annular seating *A* around a vent opening in one side of the crankcase *B*. At the inner side of the seating are formed two or more radial arms *C* to which is secured one end of an outwardly extending stem *D* which along the greater part of its length is hollow, the stem being arranged coaxially with the seating. On the stem is mounted a sliding disc closure member *E* closing down on the seating *A*. Also on the stem is mounted a slidable collar *F* between which and the closure member is arranged a short spring *G* for holding the closure member in contact with the seating with sufficient force to



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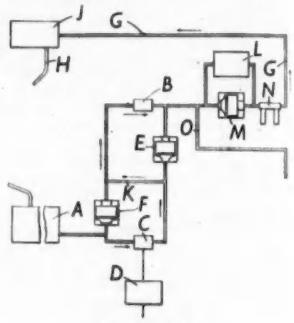
maintain a seal against normal working pressures within the crankcase. On the inner side of the closure member is formed a shallow cylindrical cavity *H* which is open to the outer atmosphere through one or more apertures *J* in the closure member, and in this cavity is contained a piston *K* which is loaded by a spring *L* such as will allow the piston to be moved when a predetermined gas explosion pressure occurs in the crankcase. In the stem are formed a number of holes containing balls *M* which engage a shallow annular recess in the collar *F*, and the balls are held in engagement with the recess by a cylindrical head *N* formed on a rod *O* contained in the stem, the head and balls serving as a catch for securing the collar in its normal position. The other end of this rod is connected to the piston *K* by a transverse pin *P* extending through slots in the stem and a central boss on the closure member as shown. The arrangement is such that when the collar is held by the catch, the spring *G*, which is supported at one end by the collar, holds the closure member tightly in contact with the seating. But when a predetermined gas pressure occurs in the crankcase the piston *K* is moved by this pressure against its spring *L*, causing the head *N* of the associated rod *O* to be moved away from the balls, so releasing the collar *F*. The gas pressure then moves the closure member to its open position. For reclosing the closure member temporarily after relief of the gas pressure and thereby preventing continued escape of oil in the form of rain or vapour from the crankcase, there is provided between the collar *F* and closure member *E* a relatively light spring *R*. The extent to which the collar can move along the stem when released by the catch is limited by a fixed collar *S* on the adjacent outer end of the stem, and for convenience in resetting the strong spring and catch, this collar *S* may be externally threaded for the attachment of a resetting tool. This tool which is represented by dotted lines at the left hand side of the drawing, comprises an internally threaded sleeve *J* which can be screwed along the collar to press the slidable spring-supporting collar *F* back to its normal position. Also the sleeve *T* has formed in its outer end a threaded hole through which a threaded push rod can be inserted for forcing the catch rod *O* to the position in which its head re-engages the balls. Preferably a cover is provided as shown for enclosing the various parts above described which extend outwards from the member *E*, the detachable cover being secured at one end to the member.—*June* 15, 1955.

INTERNAL COMBUSTION ENGINES AND GAS TURBINES

731,698. October 7, 1952.—CONTROL DEVICES, Raymond Ernest Wigg, and Ruston and Hornsby Limited, both of Sheaf Ironworks, Lincoln.

The invention relates to the control of internal combustion engines and more especially of gas turbine engines, and is particularly concerned with controls for starting and shutting down the engine. Referring to the drawing which shows the lubricating system of a gas turbine, *A* is the reservoir, *B* the main lubricating oil pump, driven by the engine, *C* the auxiliary lubricating oil pump driven by an electric



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motor *D*, and *E* and *F* are non-return valves. The pump *C* is below the level of reservoir so as to be drowned so long as there is oil in the reservoir. *G* is a pressure line feeding the engine bearings and *H* is a drain returning oil from the bearings to the reservoir. A relief valve *J* connected to the drain *G* limits the oil pressure in the pressure line to a predetermined maximum. The two pumps are connected in parallel to the pressure line and a cross connection *K* from the delivery of the auxiliary pump to the suction of the main pump enables the former to prime the latter, while the non-return valves *E* and *F* prevent short-circuiting of either pump. The oil pumps feed the pressure line *G* through a cooler *L*, which is short-circuited by a viscosity valve *M* when the pressure drop across the cooler exceeds a critical value. The cooler may have controllable shutters for varying the cooling rate. Between the cooler *L* and the pressure line *G* is a filter *N*, and upstream of the cooler is a tapping communication with a servo-oil line *O*, which conveys oil under pressure from the outlets of pumps *B* and *C* to the governor servo-motor and to the control device. Details of their construction are fully described in the specification.—*June* 15, 1955.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BIRMINGHAM EXCHANGE AND ENGINEERING CENTRE

Thurs., July 14th.—Stephenson Place, Birmingham, 2, "Automation," by F. G. Woolard, 6.30 p.m.

CHEMICAL SOCIETY

Wed. to Fri., July 13th to 15th.—The University College of the South West of England, Prince of Wales Road, Exeter, Symposium on "Recent Work on Naturally Occurring Nitrogen Heterocyclic Compounds."

SOCIETY OF CHEMICAL INDUSTRY

Mon. to Sat., July 11th to 16th.—The University, Edgbaston, Birmingham, 15, Seventy-Fourth Annual meeting.

Thurs., July 14th.—The University, Edgbaston, Birmingham, 15, Fourth Chance Memorial Lecture, "Welfare in Industry," by H. V. Potter, 11 a.m.